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# TRANSACTIONS

OF THE

# ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 46 1953

## Forty-Sixth Annual Meeting

## Macomb, Illinois

## May, 1953

APR 15 1954

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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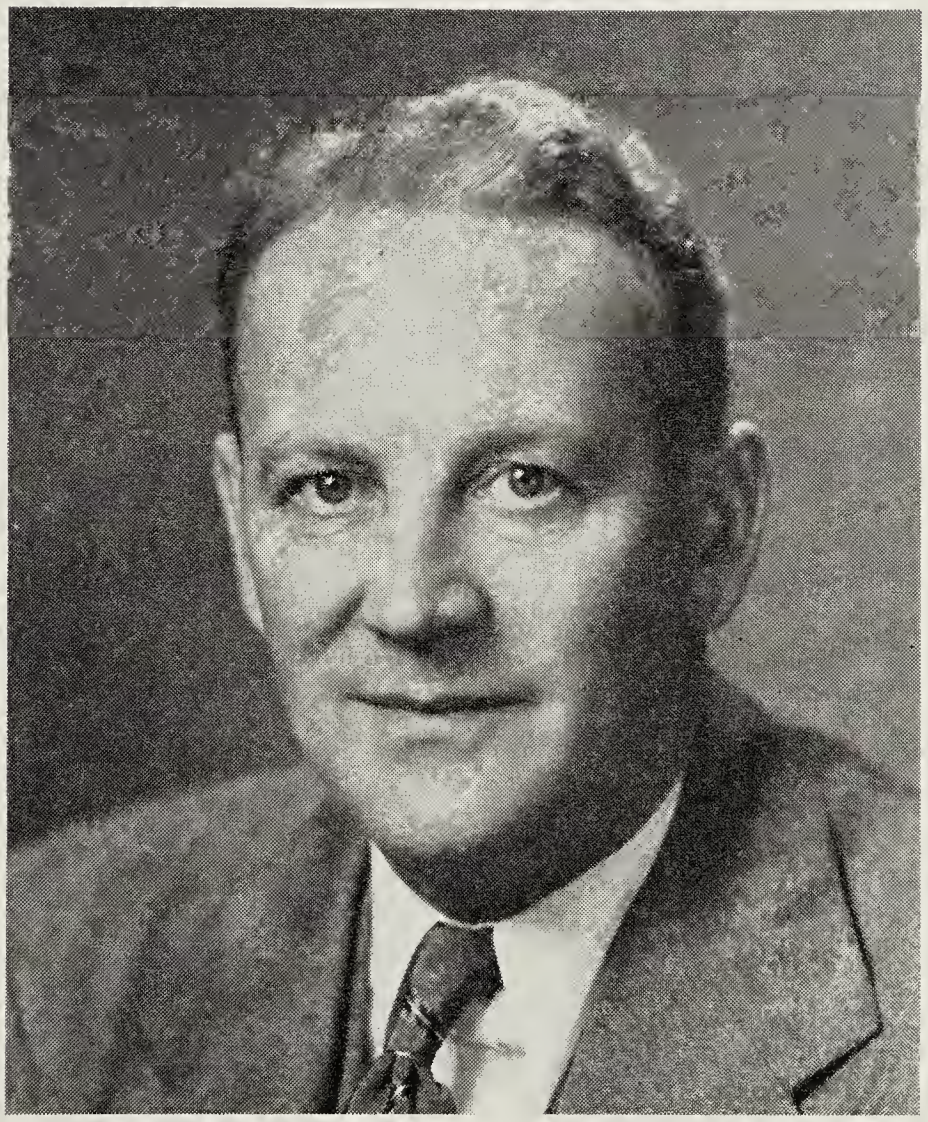
# PRESIDENTIAL ADDRESS

## TWENTY-FIVE YEARS OF ENGINEERING GEOLOGY IN ILLINOIS*

GEORGE E. EKBLAW
*President, Illinois State Academy of Science*



GEORGE E. EKBLAW, *President,* 1952-1953

On July 1, 1927, slightly more than 25 years ago, engineering geology as a distinct branch of science was first formally recognized in Illinois by the establishment of a Division of Engineering Geology of the State Geological Survey. This action developed from the work which Dr. M. M. Leighton, Chief of the Survey, had been doing for the State Highway Division for several years. It was my good fortune at that time to have been asked by him to take charge of the work of the new division. After a couple of years I was assigned the position and title of Head of the Division, a position I have had ever since.

* The presidential address as presented was accompanied by numerous lantern slides which are not herewith reproduced because of the cost.

Engineering geology as such has of course been practiced for generations—in fact, William Smith of England, who is recognized as one of the earliest stratigraphic geologists, actually was an engineer who developed that branch of science as a means of guiding him in excavation work. But in 1927 it had not been generally recognized as an independent branch of geology, and the attitude of geologists toward it was perhaps betrayed by the fact that as I engaged upon my duties my colleagues dubbed me "landslide geologist"—they might really have meant "backslide geologist."

In 1927 the number of men who admittedly practiced engineering geology could probably be counted on the fingers of two hands. Among them were such men as Berkey, Terzaghi, Wentworth, and a few others. Since then the number has increased to scores, possibly a few hundred. A separate Engineering Geology Section of the Geological Society of America was inaugurated about five years ago, and separate programs of the Section are held at each annual meeting of the Society. Engineering geology is being subdivided into special fields, such as geology of highway engineering, and programs in the separate fields are presented at various places in the country, in some cases annually, in some cases sporadically.

So far as is known, the Engineering Geology Division of the Illinois State Geological Survey was the first formal organization in that branch of science—no other nation or state in the world is recorded as having one as late as 1939.[1] Since then the U. S. Geological Survey, the U. S. Reclamation Bureau, the U. S. Corps of Engineers, other Federal agencies, many state geological surveys in this country, and many foreign national and provincial governments have established engineering geology organizations. I confess to feeling a considerable degree of pride in having been one of the early workers in this field that has developed so rapidly in 25 years.

Certainly one factor, and probably a second which has developed simultaneously, has contributed to the rapid growth of engineering geology. The first of these is the science of soil mechanics. This branch of civil engineering projects towards geology just as engineering geology projects towards engineering—they comprise a pair of links that closely couple their two parent fields. Soil mechanics, as it is now recognized, was also in its infancy in the 1920's. Professor Karl Terzaghi, whom we regard as the founder of the science, or at least of its current manifestation, was just then beginning to publish the results of his investigations and his concepts. Since then soil mechanics, like engineering geology, has developed phenomenally, so that in this country and abroad there are scores of engineers specializing in it, every engineering college of any repute has a curriculum or a department of soil mechanics, laboratories have been established, many textbooks and reference books have been written, and the field is constantly expanding.

The second possible factor is a concomitant development in soil science. Also in the 1920's Dr. C. F. Marbut of the U. S. Department of Agricul-

[1] Legget, Robert M., Geology and Engineering, p. 613, footnote. New York and London, 1939.

ture introduced into this country the Russian Glinka's concept of the soil profile, or the weathering profile, which was rapidly accepted by all scientists working with soils. For geologists and engineers it provided a guide to the recognition of significantly different zones of weathered earth materials.

In the middle 1920's the State Highway Division was completing two large bond-issue programs of paved-highway construction in the State. Along the first highways constructed, landslides, pavement settling, excessive cracking, heaving, disruption by frost, and other troublesome phenomena were occurring. When planning and constructing the highways, the engineers had not been aware of unfavorable geological conditions and their implications.

It is therefore not surprising that in the beginning most of my endeavors in engineering geology were concerned with highway problems. For 8 or 9 years about 85 percent of the engineering problems I studied were related to highways. These comprised investigations of the geologic causes of landslides, pavement heaves, and excessive settlement of fills, examination of materials in limestone quarries and sand and gravel pits to ascertain what materials were present that were deleterious in pavement and bridges built with aggregates from such sources, studies of the reaction of materials in peat bogs to accelerate stabilization of fills across them, studies of drainage conditions under highways, especially in subways and at grade separations, studies of the foundations for bridges and subway and grade separation structures, recommendations for location of borrow pits, and participation in the selection of one of several alternative highway routes which would involve the fewest or least geologic problems. In later years studies of the subgrades of proposed new highways became the most prevalent problem of highway engineering geology.

Beginning in 1935-36, problems of highway engineering constituted a smaller proportion of the engineering geology problems in which I engaged. This was partly because from our mutual studies in the earlier years the highway engineers had learned to recognize and to avoid or to treat satisfactorily those geologic situations that create difficulties. Asked if I wasn't afraid of putting myself out of a job, I replied that if I couldn't find other avenues for my efforts but had to keep the engineers in ignorance of geology in order to preserve my job, I didn't deserve the job in the first place.

Although highway problems were less numerous, those I investigated were more interesting, larger in scope, and involved more difficult situations. Landslides persisted as the largest single group of problems, but the study of subgrades became more pronounced and was a close second.

Beginning in 1936, there developed in Illinois a tremendous interest in water-supply reservoirs and recreational lakes, which has continued with the result that studies of geologic conditions at proposed damsites have constituted more than half of our endeavors since that time. Interest in reservoirs and damsites was first whetted by the Federal Public Works Administration program of

aid for municipal improvements, including better water supplies. Under this program, many municipalities too small to afford the cost of constructing water-supply reservoirs and treatment plants were able to proceed with such improvements. Warned by the collapse of the Wyandot dam in Kansas, which had been constructed under P.W.A. auspices, the P.W.A. engineers in Illinois became more cautious, and once they learned that our services were available, no dam on the P.W.A. program was approved for construction without our consultation, advice, and recommendations.

In 1945 the State Department of Conservation initiated their recreational lakes program, with the objective of constructing at least one recreational lake in each county of the State. The resulting demand for geological investigation of the proposed damsites has required most of our attention. When this program was terminated in 1949 because of the large state appropriations that obviously would be necessary to carry it out, the interest it had engendered continued. Many local organizations and groups of citizens interested in recreational activities requiring or centering in lakes were encouraged by the State Department of Conservation to sponsor the construction of such lakes. Consequently the study of damsites continues as the dominant part of our engineering geology services. The new projects of the program of recreational lakes sponsored by the State Department of Conservation, in which a large share of the funds needed for their construction is the State's allotment from the Federal excise tax on sport-fishing equipment as provided by the Dingell-Johnson bill, are included in these studies.

There is insufficient time for a discussion of all phases of engineering geology studies which we have pursued and of the geologic principles involved. Because our activities in highway engineering lend themselves best to illustration, I shall restrict discussion to this field.

Reduced to the simplest terms, most of the problems of highway engineering geology may be ascribed to excess water. Excess water contributes to landslides of all kinds, sod-creep, sloughing of cut banks, pavement heave, frost disruption, and, of course, drainage problems. Other factors also play their part, but I estimate that if we could in some miraculous way dispose of excess water under or beside our highways, we would reduce by at least 90 percent the troubles engendered by geologic conditions.

The fundamental conditions for a potential landslide are (1) the contact of two materials, one more pervious than the other, (2) water in excess of an amount the materials can absorb, and (3) an exterior slope steeper than that of equilibrium. The most favorable conditions are, in addition, (4) that the more pervious material lies above the less pervious, and (5) that the contact between them slopes downward towards the exterior slope. However, they will also occur even when the more pervious material lies under the less pervious or when the contact is flat or even sloping upward towards the exterior slope, provided the weight of the material subject to movement is sufficient. Also, landslides or rock-

falls may occur in a single material when, in the presence of excessive water or excessively steep exterior slope, the lateral component of the force from the weight of material exceeds its internal cohesion.

Under any of these conditions, whether created naturally or artificially, landslides may and do occur. Throughout Illinois they are abundant along valleys and artificial cuts, especially in deep railway and highway cuts. A typical landslide, naturally created, was encountered along the northeast side of LaMoine River northeast of Ripley in Schuyler County, in the course of a survey for the location of what is now State Highway No. 103. Here glacial till with a layer of gravel at its base lies essentially horizontally on bedrock shale. Erosion by a meander of the river at the toe of the slope oversteepened it beyond the angle of equilibrium for the material. A mass of the till extending several yards up the slope broke away and moved down and out into the river. The trees on the lower part of the slide leaned downward and outward; on the upper part they leaned backward, revealing the rotatory motion of the slide. The rupture at the upper edge of the slide created a crevasse and a vertical wall several feet high. Without the support of the material moved in the first slide, material higher in the slope then moved in a second slide, that still higher in a third slide. Surface water running into the crevasses aggravated the condition and encouraged further movement, which will continue until the entire slope is reduced once again to the angle of equilibrium. It is hardly necessary to add that when the situation was explained to the engineers, they changed the contemplated routing of the highway to avoid the landslide.

All too frequently the equilibrium of an established slope has been disturbed by making a highway cut across it, and if the conditions potential for a landslide are present, the consequence is not at all in doubt. I am glad to say that over the years I have been able to provide the highway engineers of Illinois with information which has enabled them to route many of our new highways so that they avoid most of the potential landslides.

Because in Illinois we have relatively few steep rock cliffs, rockfalls comparable to landslides do not frequently occur, but in one instance a serious rockfall of this type was narrowly averted. Along the Palisades north of Savanna, where Silurian limestone in vertical cliffs about 200 feet high lies on Maquoketa shale, the original talus at the foot of the cliffs was removed in the course of widening the highway. The removal of the talus permitted the shale to squeeze out from under the limestone, thus letting masses of the limestone settle and fall away from the rest. Fortunately, the undesirable possibilities of this situation were promptly recognized and were forestalled by replacing the talus at the foot of the cliffs. The details of this problem were discussed in a paper presented in the Geology Section of this Academy several years ago.[2]

Landslides where the less pervious material overlies more pervious material are much less frequent. A

[2] Ekblaw, George E., Cause and prevention of potential rockfalls north of Savanna: Trans. Ill. Acad. of Science, vol. 22, pp. 450-454, 1930.

typical one occurred along the highway in Starved Rock Park, at a place where Pennsylvanian shale overlies St. Peter sandstone. The highway was constructed on the shale, only a few feet above the sandstone. As the bottom of the shale was lubricated by the water along its contact with the sandstone, it slid out into the adjacent canyon, carrying the highway with it. Here the engineers fortunately could prevent further movement by constructing a retaining wall soundly footed in the sandstone.

Conditions contributing to landslides that will carry pavement away are not infrequently created when the highway is constructed with its inner part on the base of a cut in a slope and its outer part on fill built up on the slope. Where such construction cannot be avoided, the tendency for landslides can be greatly reduced by the installation of proper drains, especially on the upslope side of the highway, so that excess water can be intercepted and carried away.

Similarly, conditions favorable for landslides are created when the toe of a talus slope is transected for a highway. Because talus has no inherent cohesion, it tends to move as soon as its slope of equilibrium is disturbed. An example of this occurred in Bartonville, south of Peoria, where the downslope movement of talus that had been transected for a highway eventually destroyed several houses.[3] If a talus slope must be transected to accommodate a highway, its surface should be reduced far back, so that the new slope approximates the original.

[3] Ekblaw, George E., Landslides near Peoria: Trans. Ill. Acad. of Science, vol. 24, pp. 350-353, 1931.

A different and possibly unexpected reaction that sometimes develops when a talus slope is transected is that the pavement is heaved up. This occurs when the highway is constructed on or over a relatively soft shale formation that extends under an adjoining slope. The weight of the material in the slope over the shale tends to push it out laterally; the removal of the talus for the highway provides an avenue for the shale that is being pressed out laterally to move upward. Before its removal the talus was counterbalanced against such movement. This is one problem for which there is no solution unless it is possible to remove an appreciable amount of the material in the slope that is weighing down on the shale.

Earlier I referred to the weathering profile of soils. The topmost, usually humic, layer of a soil profile is commonly silty and porous whereas the next underlying layer is clayey and dense, usually more clayey than lower layers, because during weathering some of the clayey minerals and material from the topmost layer is transferred to the second layer. This phenomenon, especially where it is well developed, is important in engineering geology. First, the difference in texture may be so great that the two layers react differently beneath a highway, either where they are in place or where they may be segregated in a fill. Second, surface water soaks readily down through the topmost layer but is checked at the second layer. Where there is a slope this water naturally tends to flow down on top of the second layer, which becomes a lubricated surface down which the overly-

ing layer slides. This gives rise to the process known as sod-creep, whose effect can be perceived on any fairly steep slope. It is one process by which valley slopes are reduced. In highway construction sod-creep, induced or accelerated by the transection of grassed slopes, becomes a pernicious nuisance at least, because it seemingly continues interminably and often extends from the highway far up slopes in adjacent private property.

The downslope flow of surface water at the contact between the topmost and second layer of a soil profile provides additional trouble for the highway engineers. When this water comes to the brink of a cut in a slope, it runs down the face of the cut. If the material in the cut is at all silty or soft, it sloughs off and the face of the cut recedes, with concomitant troubles. Under certain conditions, the material may become actually fluid and flow out on the pavement or fill the ditches and disrupt the drainage along the highway.

It has been found that these undesirable effects can be satisfactorily controlled, if not wholly prevented, by installing at the top of the cut as near to the brow as practical a drain that will intercept the water and carry it down the sides of the slope to points of discharge where it can do no damage. These drains are installed in trenches that are backfilled with porous material to insure interception of the water; the material excavated from the trenches is cast on the downslope side to form a barrier to surface flow and further to insure maximum interception.

One of the earliest applications of this type of drainage was the installation by the Cook County Department of Highways of an elaborate system of drains on the south slope of Mount Forest Island, along the north side of what is now State Highway No. 83.[4] Because the land was a heavily wooded tract belonging to the Cook County Forest Preserve, it was imperative that the sloughing and sod-creep that started immediately when cuts for the highway were made be positively checked. The drains served the purpose admirably and the $22,500 that they cost was considered money well spent.

In south-central Illinois, where the differentiation of the top two layers of the soil profile is most pronounced, the contact between them is evident wherever the highway crosses a valley of any size. On earth roads the contact is marked by deep mudholes in wet weather and consequent chuckholes in dry weather; on pavements the contact is always a zone of excessive seepage and potential pavement disruption. Cross-drains under the pavement and porous subbase are essential to correct the situation.

In the early years of our engineering geology work, peat bogs provided a frequent problem in highway engineering, especially in northeastern Illinois. Even where a paved highway followed what appeared to be a stable earth road across a bog, the fill for the pavement or the heavier traffic over it often was sufficient to cause settlement or collapse. Investigations revealed that in most instances the bogs were covered by a

[4] Ekblaw, George E., and Campbell, D. M., A noteworthy example of drainage to prevent landslides: Illinois Engineer, vol. VII, no. 8, p. 3 and 6, December 1931.

mat of peat underlain by muck. The muck was more or less fluid and had little or no bearing power, yet the peat mat apparently had sufficient tenacity, supplemented by the slight support afforded by the muck, to uphold the light horse-drawn traffic over the earth roads but not enough to support the paved roads and motor traffic.

Considerable difficulty was encountered in constructing across a bog a fill that would remain stable. A fill that at first appeared complete and satisfactory might subsequently settle or collapse. Several methods were tried and eventually a most effective one was devised. A fill was constructed across the bog as rapidly as possible, whose height was at least as great as the depth of the bog plus the desired height of pavement above the bog and whatever width was required to maintain the height. Then through the fill and down to the bottom of the bog, holes were drilled at predetermined intervals in 3 or 4 longitudinal lines parallel to the highway, one along each side and one or two in the center. Charges of explosives were set in the portions of the holes that were in the muck, and then detonated, the two outer lines momentarily ahead of the inner line or lines. It was reported that when this method was first put into practice, in a bog forty feet deep near Elgin, the fill rose en masse as the explosive was detonated and then settled down into the bog surprisingly close to the calculated grade for the highway.

Subsidence of fills in other incompetent mucky areas is not uncommon. Usually there is lateral movement away from as well as lowering under the fill. A typical example of this phenomenon occurred a few years ago when the heavy fill for the new route of State Highway No. 13 southeast of East St. Louis was built across the Mississippi River bottoms. Again explosives were used to accelerate settlement of the fill, and the material that was moved laterally away was salvaged by large draglines that pulled it back into place.

More recently, during the construction of a fill for the new route of U. S. Highway No. 40 across Little Creek east of Marshall, in Clark County, where test borings had indicated that laminated clay underlay the stream alluvium, the weight of the fill caused the clay to yield. As a result, heaves occurred along the south side of the fill, the side of the fill moved downward and outward much like a landslide, the south wing-walls of the concrete box-culvert were pulled away, and the south section of the box-culvert was separated from the north section. A reduction in the height of the fill served apparently to check the movement.

Unfortunately there is insufficient time to discuss in a similar manner all the other types of geologic problems in highway engineering or the problems involved in our studies of damsites. However, I cannot pass this opportunity to remark the admirable procedure which the State Department of Conservation adopted for the investigation of damsites for their program of recreational lakes. Suggestions for possible damsites were universally solicited, and literally hundreds of sites were proposed. The engineers of the Department investigated the sites and if it was decided that they merited further

study, fundamental data, including area and volume of the proposed lake, drainage area, run-off, possible pollution, percentages of wooded pasture and cultivated land, distance from population centers, and so forth, were compiled. These preliminary engineering reports were submitted to several agencies, among which were the State Geological Survey, the State Natural History Survey, the State Water Survey, the Soil Conservation Service, the State Waterways Division, and the several Divisions of the Department of Conservation itself. If any of these agencies for some reason considered a proposed site unfavorable, it was eliminated from further consideration.

Damsites approved tentatively by all agencies were then surveyed by the Department of Conservation engineers. The resulting preliminary plans for the proposed damsites were submitted to us to determine where test-borings should be made. We studied the samples from the test-borings and interpreted the geologic conditions, all before the final design of the dam was drafted. Thus all possible precautions were taken to insure a safe, satisfactory dam.

Our work with highways and dams has been emphasized, but there has been also a host of miscellaneous problems, some of which have been very important. These include studies of subsidence over mined-out areas, among which the study of an area in southeast Springfield several years ago and of the Peoria airport recently are outstanding, sewer excavations, park sites, river locks, pollution problems, drainage problems, foundations of buildings and structures, and many others. Of these miscellaneous problems those of drainage and foundations are most numerous.

There is no time to discuss all of these, but you may be interested in one which I regard as the most unusual I have encountered in my engineering geology experience. On my return to the office after a day in the field a few years ago, I found that I had been committed to an immediate investigation of an explosion of a grave in a cemetery at a nearby town. When I arrived at the town, I learned that the burial was 40 to 50 years old and was in an underground concrete vault that had been built around the casket. I also learned that as news of the explosion had spread about, so many people had come to see it that the cemetery officials had put a fence around the lot. After being assured that the officials of the cemetery and relatives of the deceased sanctioned excavation of the grave, we proceeded to the cemetery. It was immediately apparent from the assemblage already present and steadily increasing that my expected arrival had not passed unnoted or unheralded.

I think you can imagine my feelings, as, totally ignorant of what we should discover, it was necessary that I proceed to direct operations for the investgation before the eyes of such a crowd, who I felt were undoubtedly almost as curious to see how the "expert" would conduct his investigation and how he would arrive at a decision as to see what would be discovered. After definitely eliminating all possibility of any human participation in the event, our ultimate interpretation was that gas leaking

from the supply main that ran underground not too far from the cemetery had followed tile drains into the cemetery, had accumulated in the burial vault, and had been ignited by a thunderbolt. In support of this interpretation were the facts that (1) there had been a thunderstorm in the vicinity during the 2-3 days that had elapsed between the day the caretaker had mowed the grass in the lot and the day he noted the disturbance of the grave, (2) a lady living near the cemetery reported that during the storm she had heard a detonation which she could hardly believe was ordinary thunder, and (3) a week or so later newspapers reported two incidents elsewhere in the country where thunderbolts had detonated accidental accumulations of gas in underground chambers under construction.

This demonstrates the range and variety of the work of an engineering geologist in a single state. Each day holds the possibility of something new and different. Less than a year and a half ago a new field of study—the excavation of subterranean chambers for storage of liquid gases—opened up and since then has occupied much of our time. We regard the past with considerable gratification and we await the future with equal anticipation.

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# MORNING ADDRESS

## SCIENCE IN THE HIGH SCHOOL CURRICULA

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The place of science in the high school program is a subject that has been discussed by various groups from time to time over a long period. The importance placed upon it is determined somewhat by the group and their general interest in science in the high school program. The importance and recognition of the place of any particular subject will vary from group to group. I presume this is an advantage, because it keeps each subject area group conscious of each of the others, and at the same time requires the various subject groups to be well informed as to the contributions which each subject area can and will make to the general education program of our high school youth.

The importance of any particular field of study in the preparation of our youth cannot be passed off with general conclusions today as it may have been, let us say, at the turn of the century. The obligations of education in our modern scientific, technological, and ideological world imposes a serious burden upon the school if we are to prepare our youth to live successfully and to compete in our modern world. I believe it is necessary today in formulating the program of training for young Americans to give them as much information as possible in all areas of human endeavor so that they may be prepared to at least think in all of the areas which will modify and change their environment. Since all of these areas have a great deal of valuable material it becomes necessary to evaluate carefully the kind of subject matter and the areas which must be emphasized in order to plan a well-balanced training program.

No one can deny that science is one of the most important areas of training. Every living being is faced with the existence and effects of scientific principles every living minute. Each individual is a scientific bundle of facts—a living chemical laboratory. Every living thing represents chemistry at work as well as other phases of science.

When some portion of this chemical laboratory of life fails to function, a scientist skilled in that particular field must be called to determine the cause of this failure. To human beings this scientist is known as a doctor. In his examination and inquiry into the affected area, it becomes necessary at times for him to call upon other skilled scientists to assist him in determining the cause for failure. If it is possible to determine the cause of the failure or weakness, the physician then is in a position to prescribe treatment, which in many instances involves the adminis-

tering of other chemicals to assist in the correction. Or, some other phase of science may have to be utilized.

In agriculture when soil fails to give back to man what is expected or desired, he turns to a specialist in soil science to determine the cause, and when discovered, to recommend scientific treatment of the soil in order to restore its productivity. Usually it is a soil chemist who makes the analysis and prescribes the treatment.

When man in his ever-changing environment is faced with the need for a new machine, or, for instance, the construction of a bridge, a different type of scientist is called to work upon the problem and to prescribe, and as a result of his efforts, new machines are invented to lift burdens from and solve problems for mankind.

When man in his searchings discovers some new material previously unknown to man, a scientist is called to determine the content of this new material and to help determine the uses to which it can be put to serve mankind.

When progress has been made in certain areas and man is led to believe that a new force is suspected to exist in hidden areas, another scientist is called to begin research to determine the nature of the force —how it can be unlocked and made available. For a long time before the discovery of how the atom could be split and its force utilized, man was conscious of or believed that there was such a hidden force. The challenge was how to unlock this force to make it available. A few years ago this problem was at least partially solved. We hope and anticipate that for the most part this enormous force will be used to benefit mankind, but at the same time we know that scientific discoveries have also been used to destroy mankind.

We may state that all progress made by man from the beginning of time in the area of the physical world rests upon the work and the discoveries of scientists in some area. I believe we could agree that some of the improvements and strengthening of our belief in the spiritual side of man's life have come about as a result of knowledge gained in some phase of science. Yes, even the belief in our basic philosophy of the existence of God and the improvement of our spiritual welfare has been enhanced and strengthened as a result of our constant forward march in scientific areas.

Accepting the foregoing statements as true, it becomes evident that if man is to understand the world, the environment in which he lives, he must have at least some basic fundamental knowledge in the areas of science. Hence, in outlining the program of training for youth in our elementary and high school courses, we cannot neglect the importance of this area of essential knowledge.

Too often, it seems to me, the outline of subject matter which makes up our curriculum has not been well planned—especially in the field of science. In my humble judgment I feel that the scientific portion of our training program should be a continuous and developing program of study starting at the beginning of our formal education in the kindergarten or first grade. It should grow progressively and should be adapted to meet the particular grade level

in which the subject matter is utilized. It should thus continue in an orderly and well-organized fashion from the kindergarten through the high school.

There may be those programs of preparation in science for our youth which have a tendency to wander toward the realms of specialization, especially in the elementary school. I do not believe that this is good for the best interests of the program and the learner.

In the elementary school, especially in the middle and lower grades, it is not as important to study basic scientific principles as to use text material which recognizes and contains these fundamental principles without setting them forth as such. In this area, I believe it is essential that the child grow to understand his relationship to the scientific world in which he lives—the production of life in both the plant and animal kingdoms, and man's dependence upon these plants for his very existence.

In the upper grades it is essential that youth learns the importance, for example, of a balanced diet and its contribution to his physical welfare and to his general happiness and well being. The elementary school child should also be instructed in the areas of science which teach him why it is important that he learn to take proper care of his chemical laboratory which forms the house in which he lives.

Such a general outline as this should be so well worked out that at every grade level the material would be adjusted to the understanding of that age group. In many instances some of this material can be well integrated with other areas or subjects so as not to make the material too elaborate or voluminous. I believe in addition to this it would be possible, even in the elementary school, to prepare additional scientific materials to be used by those children who show strong potentialities in the field of science and who at the same time possess what, for lack of a better term, we call a "high intelligence quotient." In approaching this problem, teachers in the classroom must recognize that if the hidden potentials of our children are to be developed, we must offer continuous challenges to them which will whet their appetities, increase their desires, and help them to progress in the ever-challenging world in which we live.

In high school it is possible to offer a new specialized approach in the field of science. We move into the areas of chemistry, physics, biology, earth science, and health. It is possible then for the student to learn and understand the chemistry and physics of the world in which he lives and how dependent man is upon this knowledge if he is to live understandingly, successfully, and happily.

In both the areas of elementary and high school scientific courses, the school should utilize as source material, insofar as possible, the local environment in which the student finds himself. This tends to tie together the purely scientific phase of man's interest and the practical side of man's life. It enables the teacher to make clear to the student the importance of both of these areas in the life of human beings.

I recognize that probably not all students should be required to study

these specialized fields of science. But the courses should be required of all students who show that they possess excellent scientific potentials, a high degree of intelligence, or special potentials in the field of teaching, research, medicine, physics, engineering and chemistry. I believe that the teacher of science has a responsibility to the student to discover, if possible, some of his tendencies and, when discovered, to afford him the opportunity of further developing these potentials.

I am not well enough informed on the outline of high school courses to know whether or not the following idea is in existence or whether it is a practical one, but I do believe it holds a challenge which might well be considered and utilized, especially in large high schools where it can be organized for the benefit of that group of students who show the potentials to which I have referred.

The idea is this: That it may be well to offer as elective courses certain prerequisite courses in the specialized fields of science which would enable the instructors to discover the students' likelihood of scientific potentials in any particular science area. When these courses have been completed, the school should organize more specialized courses in certain areas of science which would give the more gifted child greater challenges in fields of exploration and so assist him in developing these hidden qualities. As I say, I am not sure whether or not this principle is used in our American high schools, but I believe it is worthy of consideration if we are to offer to the more able group of children greater challenges than the general courses offer at present. It might be well for those who show ability to be classified into groups where they could move forward more rapidly, especially in the general courses. This would permit them to go into the more specialized courses at an earlier date and complete them within the prescribed period of time which we usually allot to the secondary school.

I have heard it charged that in some high school courses of study there has been a tendency to reduce rather than to enlarge the science offerings. Where this has been the practice, I am of the opinion that it would be impossible for the teacher to have sufficient opportunity to discover the hidden potentials of those who come under his instruction. This could have bad results, not only in helping the child discover his talents, but also in denying to the scientific world, abilities which we all know are needed now more than ever before.

Many of our high school courses have been organized around the theory that high school science courses should be chiefly concerned with the presentation and memorization of scientific facts. It is true that a certain amount of this is necessary, but for the most part the courses should be organized on the problem-solving basis. I believe, too, that many scientific facts will be more easily learned and mastered when approached from the problem-solving point of view rather than from the point of view of merely memorizing the facts as such. You in this organization, are very conscious of this. However, I believe that you have a responsibility to the other areas of education in making known

to them these conditions, for the reason that no particular subject of study in the high school is wholly independent of all other areas of study. The high school program of training is an overall program and each subject is interrelated with the other, and we must recognize this in outlining and organizing the program of education in our secondary schools.

In utilizing the "problem-solving" method of approach, the student begins to learn what I conceive to be the difference between *re*search and re*search*. I have known individuals in my time who used these words interchangeably. While it may be true that the dictionary might not make a distinction, I believe that from the scientific point of view there is a real difference. The first, *re*search, as I conceive it, means merely a review of the areas already covered, to discover known facts and principles; but the second term, re*search*, means a critical and exhaustive investigation, possibly through experimentation, in an effort to discover new principles and unknown facts. Handling courses in science in this fashion, when properly directed, gives the student fundamental and important training in the scientific approach and tends to develop techniques in the field of research. It leads him, and I think desirably so, to the point where he is not willing to accept the expression of a mere opinion, but rather to examine critically to discover whether or not a given statement is true or false.

As I have already pointed out above, it is the duty of every teacher, including the teacher of science, to help each student discover his hidden potentials, to utilize every opportunity to encourage the child from kindergarten through the high school to enter into activities and projects in an effort to help him to discover his talents, and when once discovered, to lend to him every encouragement and opportunity to develop that hidden gift at the particular grade level in which the child finds himself at any particular period of time as he moves through the formal educational program.

To me this is highly important, because today as never before, our very existence as a nation depends upon the successful training and development of the abilities of our young people in all areas of learning, and especially in the fields of science. Under our system of government, with our concept of freedom and liberty, the individual is free to direct his talents any way he sees fit and should be allowed to push the horizon farther out in his particular specialization. To make such opportunities possible places a heavy responsibility upon the teachers in our classrooms, from kindergarten through high school, but they must carry it if we are to give our best.

Today with various types of ideologies competing in their efforts to prove which is best, the free mind is more important than ever before. You and I as teachers, and you in the field of science, must constantly strive toward and always emphasize this important principle. It is only with the improvement and the utilization of this basic philosophy that we will be able to maintain what you and I believe to be most important—free people with free minds in a free society.

To make it clear why I place so much importance on the above, we can turn to the work-a-day world to see how great our national need is in the various fields of science. We must continue to develop constructively to meet those ever growing needs.

(1) It is well known that the field of nursing is in great need of more skilled people if we are to look carefully and methodically into the curative field of human ailments. Along with the need for nurses, we are all very conscious of the fact that our country needs more good doctors. Unless we move conscientiously forward in our training areas with the knowledge of these shortages and utilize every opportunity to encourage and develop the potentials in our youth, these needs will never be met.

You are well acquainted with the high quality of academic preparation which is needed in the field of medicine. For instance, in our own University of Illinois College of Medicine, for several years now, no prospective doctor has been permitted to enter unless his scholastic average was at least 4. This means that you and I have to shoulder a responsibility in pointing out to the student the necessity of constant and earnest application during his period of preparation if he shows potentials and has a desire to enter this specialized field. While it is true that good doctors may come from those who do not meet this requirement, yet due to lack of facilities to train, it becomes necessary as a screening device to select those with a high quality of preparation. As a result of the standards which have been at least temporarily adopted, seldom do they have failures because of lack of ability.

(2) The same story can be told in the area of physical sciences: engineers are in great demand, and so are capable physicists, research chemists, research specialists in physiological sciences.

These illustrations point out the necessity and importance of our efforts in helping the nation to discover the young peoples' potential abilities and the use to which they can be turned. This general responsibility rests only in part on the shoulders of the high school teachers in the field of science. But the high school science teachers have an opportunity which, to the best of my knowledge and belief, has not been utilized as it should be. I believe that they have a responsibility of working with the teachers in the elementary schools in helping to develop and to organize desirable material which should be included in elementary science courses. I think the high school teachers of science would render a great service to the youth of this nation if from time to time they could meet with the elementary teachers interested in science and point out to them some of the responsibilities which they owe to the children in addition to that of merely instructing or teaching the materials at hand. This kind of cooperation and support would greatly strengthen the elementary courses and encourage the teachers to render to children an even greater service than they are giving today. I believe that when work of this type is done in the elementary school, the child who enters high school comes better prepared and with a better attitude than

he would otherwise possess. I am not sure just what has been done in this particular area, but I believe it is a challenge to the high school teachers of science.

Of course, I recognize some of the problems with which you will be faced when approaching this problem as I have suggested. The approach can come through an overall study of curriculum work. It can come in general teachers' meetings. If these meetings are democratically developed as they should be today, the subject could be planted in the minds of the elementary teachers so that the request would come from them. This, to me, would be most desirable for it has been my experience that when individuals suggest problems for study, they approach the problems with more enthusiasm, and as a result, the outcomes are more substantial, more applicable, and so more useful than they otherwise would be. We must remember in handling this particular problem that the formal training of the elementary teacher requires only a small amount of preparation in the field of science. This must be recognized when offering help and suggestions to them.

There is one other suggestion which I feel that I should make before closing. I am certain that as teachers, and more especially you as teachers of science, are often approached by youngsters who have the idea that all discoveries have been made, all the frontiers have been eliminated, and that there is no challenge for youth today. How very wrong those youngsters are, words fail to relate. In my judgment the youth of today is faced with greater opportunities and challenges than youth of any previous generation. Science and technology have opened up new frontiers which to date have only been glimpsed. Let me give one illustration to make clear what I mean. Recently it was my privilege to talk with an internationally known chemist. We discussed only one area of knowledge in this vast field of chemistry, the soy bean. This chemist informed me that the number of products which are now coming from the soy bean and which have been made possible by the industrial chemists is small compared to what the potentials are in that particular area. He stated further that in his humble scientific judgment there was no one particular thing which human beings need and desire which cannot, through the field of chemical research, be found in the soy bean. The challenge is one of the greatest which human beings have ever faced.

We can also turn to the area of technology, the field of engineering, and allied fields. The challenges are as great and, yes, I think the area of science has more to offer in the way of frontiers in this modern day than any frontiers faced by generations of the past. We might add, too, that the field of medical research and efforts to discover treatments for the relief from human suffering and pain is just opening up. We all know that in the last few years large amounts of money have been spent and many people have been working in the field of medical research in an effort to find relief and curative treatment for such diseases as polio, cancer, and others. Yes, the place of science in the high school program must be balanced with the total pro-

gram, but its importance cannot be overemphasized because there is no area of human interest, human welfare, and human security which these scientific areas do not touch and modify. It seems to me that these are challenges which you and I as teachers must face and to which we must apply all our abilities if we are ever to give our high school students the opportunities which I have enumerated, as well as others left unsaid. To the degree that we succeed we shall make available the great latent potentials of youth for the future welfare of our nation.

## PROGRAM FOR THE 46th ANNUAL MEETING

## PAPERS PRESENTED

# ARCHAEOLOGY AND ANTHROPOLOGY

C. W. HUDELSON, *Chairman*
*Illinois State Normal University, Normal*

Our Heritage from the American Indians: Romeo B. Garrett, Bradley University, Peoria.

A Preliminary Report on Salt-making and Pottery Manufacture at a Prehistoric Site near the Saline River in Gallatin County, Illinois: Irvin Peithman, Southern Illinois University, Carbondale.

The Grand Kickapoo Village and the Stockaded Fort: William B. Brigham, Bloomington.

Fiedler Site in Fulton County: Dan Morse, M.D., George Schoenbeck, and Dan F. Morse, Peoria.

History of the Illinois State Archaeological Society: C. C. Burford, Urbana.

Excavation in Dickson Mounds State Park: Don F. Dickson, Lewistown.

Memorial Tribute to Frank W. Aldrich: C. W. Hudelson, Illinois State Normal University, Normal.

# BOTANY

JOHN W. VOIGT, *Chairman*
*Southern Illinois University, Carbondale*

*Composition Diagrams for Forests: Examples from Two Illinois Stands: Arthur G. Vestal, University of Illinois, Urbana.

*Diagrams to Show Which Species Occur in Particular Plots or Stands: Arthur G. Vestal, University of Illinois, Urbana.

Some Problems in Forest Planting in Illinois: J. Nelson Spaeth, University of Illinois, Urbana.

*The Flora and Ecological Analysis of the Vegetation of the Funk Forest Natural Area, McLean County, Illinois: Robert T. Calef, University of Illinois, Urbana.

*Recent Advances in the Field of Forest Genetics: Leon S. Minckler, Carbondale Research Center, U. S. Forest Service, Carbondale.

The Effect of the $sh_2$ Factor on Carbohydrate Reserves in the Mature Endosperm of Maize: John R. Laughnan, University of Illinois, Urbana.

Coenopterid Ferns from the Pennsylvanian of Illinois. I. Anachoropteris clavata: Theodore Delevoryas and Jeanne Morgan, University of Illinois, Urbana.

Coenopterid Ferns from the Pennsylvanian of Illinois. II. A Previously Unreported Member: Jeanne Morgan and Theodore Delevoryas, University of Illinois, Urbana.

An Apparently New Virus Disease of Tomatoes: Patrick M. Miller and H. H. Thornberry, University of Illinois, Urbana.

Relationship between Morphology of the Colony and Method of Cell Division in Bacillus cereus var. mycoides: Sister Mary Cecilia Bodman, Mundelein College for Women, Chicago.

Vascular Plants of Southern Illinois: Wm. M. Bailey and Julius R. Swayne, Southern Illinois University, Carbondale.

A Virus Disease of Horseradish: Donald Hickman, University of Illinois, Urbana.

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* Published in this volume.

# CHEMISTRY

G. R. YOHE, *Chairman*
*State Geological Survey, Urbana*

*Survival Following Treatment with Sulfones in Experimental Tuberculosis in Guinea Pigs: Ben C. Sher and John M. Kloeck, Municipal Tuberculosis Sanitarium, Chicago.

*Microscopy and Color Photomicrography in the Study of Feedstuff Quality: Albert J. Gehrt and W. P. Elmslie, Moorman Manufacturing Co., Quincy.

*Flavor and Vitamin Stability in Fluid Milk: Herman W. Dorn, Dorn and Co., Decatur.

Outcomes of the Monmouth Conference of College Chemistry Teachers: Ben T. Shawver, Monmouth College, Monmouth.

Conductivity Measurements of Organic Liquids by Ballistic Galvanometer and Condenser: Garrett W. Thiessen, Monmouth College, Monmouth.

*Reaction of Epoxides with Mercaptans: Sulfones: Edward G. Rietz, Wright Junior College, Chicago.

*Some Factors Influencing the Suspension Polymerization of Styrene-Divinylbenzene Mixtures: Carl R. Meloy, University of Illinois, Navy Pier, Chicago.

New Products from the Glass Industry: George F. Stockdale, University of Illinois, Urbana.

# GEOGRAPHY

BYRON K. BARTON, *Chairman*
*Eastern Illinois State College, Charleston*

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# BOTANY

## COMPOSITION DIAGRAMS FOR FORESTS

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There is still much room for new methods in obtaining field data for study of vegetation and in summarizing and depicting the facts after they are found. One rather simple way of showing the character and make-up of a forest is by use of composition diagrams and tables. Such diagrams show for a forest area or for a set of plots the average size and the number of the trees of each important species. The species are arranged in order of some measure of relative importance, here basal area per acre. (Basal area of an individual tree is the cross-sectional area in square feet of its trunk, measured at breast height.) For each species a bar or rectangle shows by its height the number of trees per acre; by its width, basal area per tree. The area of a bar shows basal area per acre. It is a fairly dependable measure of relative significance of that species in terms of bulk or of area covered. Numerical values of these and related quantities are shown in the composition table.

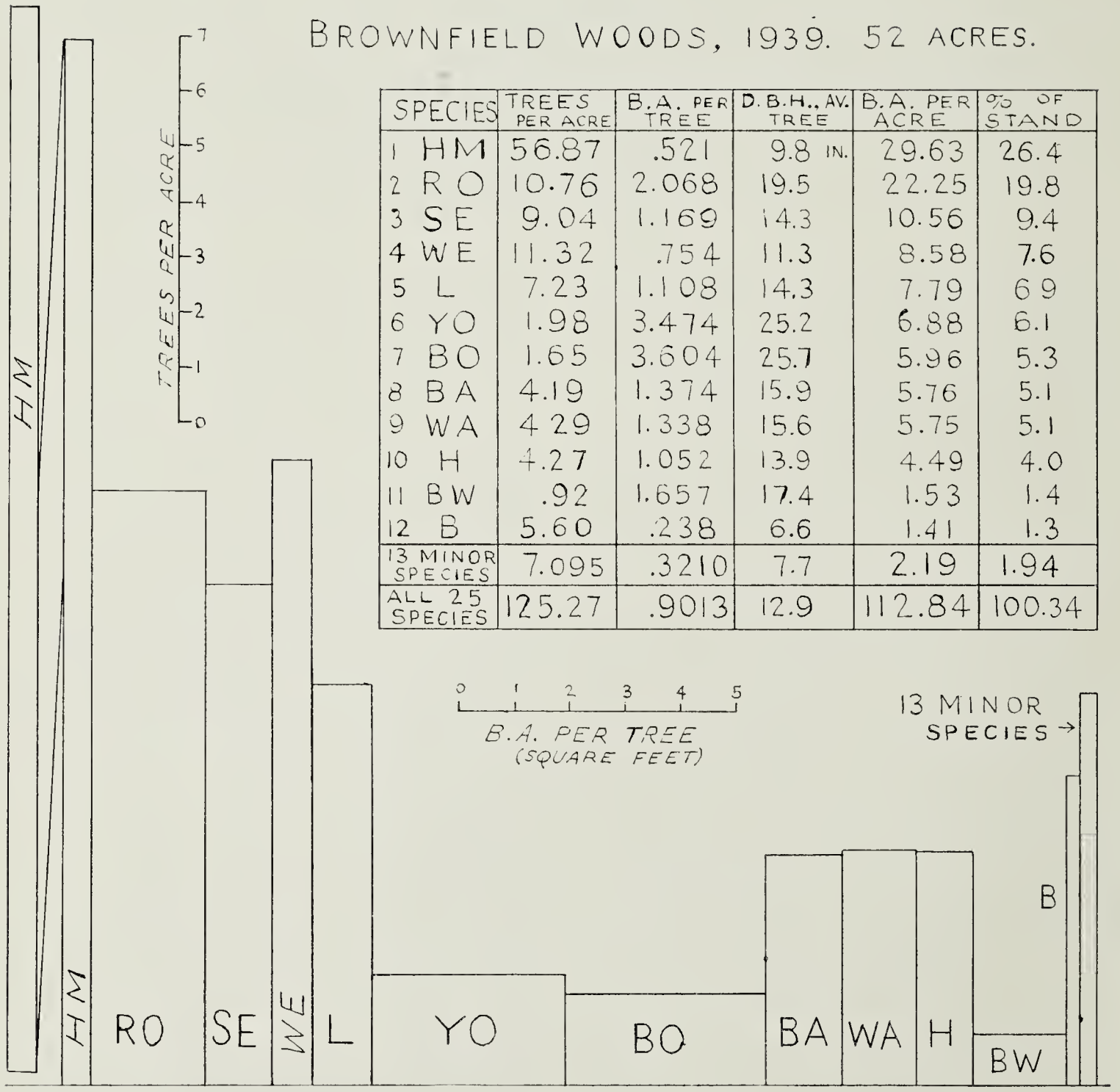
The first example (fig. 1) shows the make-up of a little-disturbed old-growth stand near Urbana that has been much studied. The 52-acre sample is complete except for smaller trees of the eight most common species, for which the numbers were estimated from values for all sizes in 12.8 acres and from all larger trees in 39.2 acres. It covers the upland part of Brownfield Woods (omitting a flood-plain area and the outer margins). All trees three inches in diameter or larger are included. The survey was made the autumn of 1939. The twelve leading species, with symbols, are shown below.

As may be seen from the table, the thirteen minor species make up less than two percent of the stand.

It is seen at once that there is great difference among the species and little relation between average size and number of trees.

Three species attained enormous dimensions in this forest, bur oak 54 inches diameter, yellow oak 49.5 inches, walnut 44.5 inches (estimated

| | | |
|---|---|---|
| Acer saccharum | hard maple | HM |
| Quercus rubra | (northern) red oak | RO |
| Ulmus rubra (U. fulva) | slippery elm | SE |
| Ulmus americana | white elm | WE |
| Tilia americana | basswood, linden | L |
| Quercus muhlenbergii | yellow oak | YO |
| Quercus macrocarpa | bur oak | BO |
| Fraxinus quadrangulata | blue ash | BA |
| Fraxinus americana | white ash | WA |
| Celtis occidentalis | hackberry | H |
| Juglans nigra | black walnut | BW |
| Aesculus glabra | buckeye | B |




| SPECIES | TREES PER ACRE | B.A. PER TREE | D.B.H., AV. TREE | B.A. PER ACRE | % OF STAND |
|---|---|---|---|---|---|
| 1 HM | 56.87 | .521 | 9.8 IN. | 29.63 | 26.4 |
| 2 RO | 10.76 | 2.068 | 19.5 | 22.25 | 19.8 |
| 3 SE | 9.04 | 1.169 | 14.3 | 10.56 | 9.4 |
| 4 WE | 11.32 | .754 | 11.3 | 8.58 | 7.6 |
| 5 L | 7.23 | 1.108 | 14.3 | 7.79 | 6 9 |
| 6 YO | 1.98 | 3.474 | 25.2 | 6.88 | 6.1 |
| 7 BO | 1.65 | 3.604 | 25.7 | 5.96 | 5.3 |
| 8 BA | 4.19 | 1.374 | 15.9 | 5.76 | 5.1 |
| 9 WA | 4 29 | 1.338 | 15.6 | 5.75 | 5.1 |
| 10 H | 4.27 | 1.052 | 13.9 | 4.49 | 4.0 |
| 11 BW | .92 | 1.657 | 17.4 | 1.53 | 1.4 |
| 12 B | 5.60 | .238 | 6.6 | 1.41 | 1.3 |
| 13 MINOR SPECIES | 7.095 | .3210 | 7.7 | 2.19 | 1.94 |
| ALL 25 SPECIES | 125.27 | .9013 | 12.9 | 112.84 | 100.34 |

FIG. 1.—Composition diagram and table for 52 acres of upland mixed forest in Brownfield Woods in 1939.

from largest stump). These have been on the decline for some years, with few small trees to replace them. Some cutting over many years, mostly of oaks and walnut, has greatly accelerated the increase of hard maple, represented in 1939 by three times as many small and middle-sized trees as are necessary to maintain the observed population of 124 large maples (18 to 36 inches d.b.h.). Consequently the diagram shows a small average size (9.8-inch d.b.h.) with very high density (nearly 57 per acre: 2,958 maples in all). Only one species, red oak, shows large average size as well as fairly high density.

The second diagram and table (fig. 2) are for a large sample in the same forest from the same 1939 survey. It comprises 16 plots each of 0.8 acre size. These differences show in the diagrams: hard maple has nearly 8 more trees per acre; white elm is in 8th place (instead of 4th); bur oak is in 10th place (instead of 7th). This 24.6-per cent sample is a

BROWNFIELD WOODS, 1939. 12.8 ACRES

| SPECIES | TREES PER ACRE | B. A. PER TREE | D.B.H., AV. TREE | B. A. PER ACRE | PER CENT OF STAND BY NO. | BY B. A. |
|---|---|---|---|---|---|---|
| 1 HM | 64.59 | .520 | 9.8 | 33.60 | 51.2 | 29.4 |
| 2 RO | 8.36 | 2.375 | 20.9 | 19.85 | 6.6 | 17.4 |
| 3 SE | 9.22 | 1.243 | 15.1 | 11.46 | 7.3 | 10.0 |
| 4 L | 7.58 | 1.193 | 14.8 | 9.04 | 6.0 | 7.9 |
| 5 YO | 2.27 | 3.433 | 25.1 | 7.78 | 1.8 | 6.8 |
| 6 BA | 4.38 | 1.674 | 17.5 | 7.33 | 3.5 | 6.4 |
| 7 WA | 4.61 | 1.522 | 16.7 | 7.02 | 3.7 | 6.1 |
| 8 WE | 9.61 | .684 | 11.2 | 6.58 | 7.6 | 5.8 |
| 9 H | 3.67 | 1.055 | 13.9 | 3.87 | 2.9 | 3.4 |
| 10 BO | 1.25 | 2 792 | 22.6 | 3.49 | 1.0 | 3.1 |
| 11 B | 5.94 | .245 | 6.7 | 1.45 | 4.7 | 1.3 |
| 12 BW | .63 | 2.066 | 19.5 | 1.29 | .5 | 1.1 |
| MINOR SPP. (10) | 3,98 | .374 | 8.3 | 1.49 | 3.2 | 1.3 |
| ALL SPP. (22) | 126.09 | .906 | 12.9 | 114.25 | 100.0 | 100.0 |

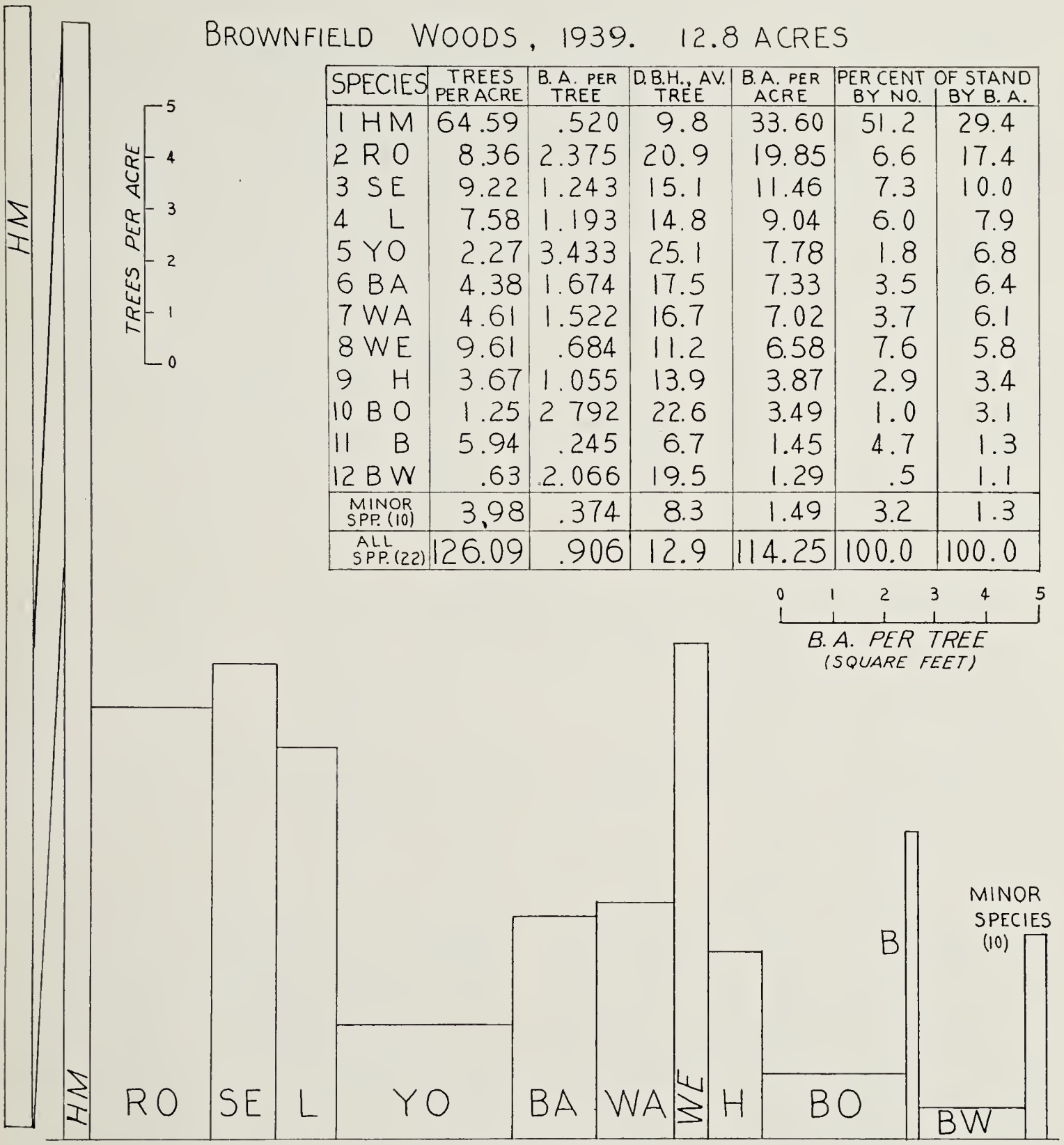
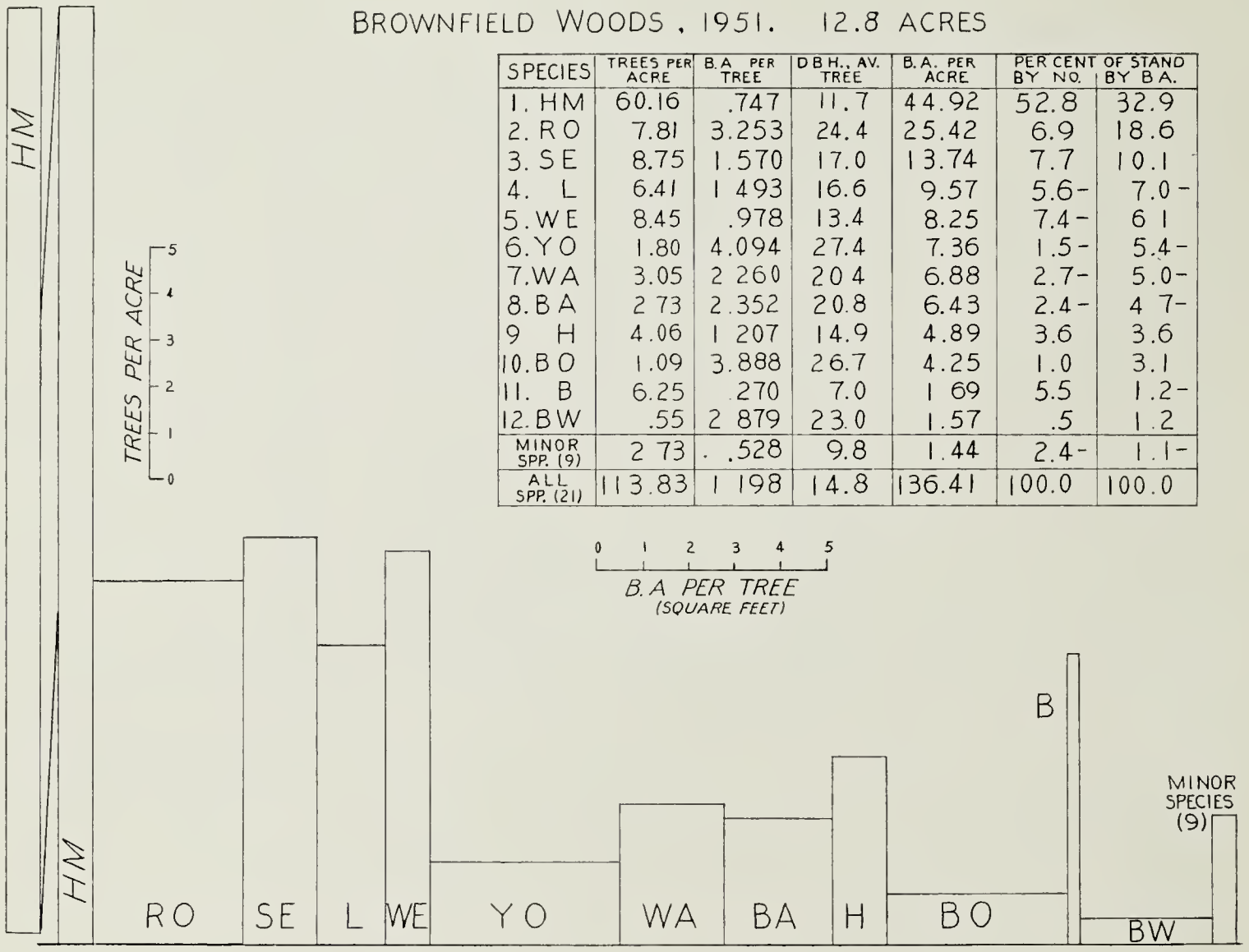



FIG. 2.—Aggregate of 16 plots, each 0.8 acre, Brownfield, 1939.

less faithful reflection of the stand as a whole than one might expect. The same may be true in greater degree for many smaller forest samplings commonly thought to be adequate.

The third diagram and table (fig. 3) are for the same 16 plots as resurveyed 12 years later by Dean F. Cortright. We now note a change in the appearance of the diagram as a whole: it is lower and broader, showing that most species have increased in average size and decreased in number of individuals. Hard maple, with 4½ fewer trees per acre, has advanced in bulk from 29.4 to 32.9% of stand. White elm is up from 8th place to 4th. Linden, yellow oak, both species of ash, buckeye, and the minor species have lost ground. Two minor species have been lost, one




| SPECIES | TREES PER ACRE | B.A PER TREE | D.B.H., AV. TREE | B.A. PER ACRE | PER CENT OF STAND BY NO. | PER CENT OF STAND BY B.A. |
|---|---|---|---|---|---|---|
| 1. HM | 60.16 | .747 | 11.7 | 44.92 | 52.8 | 32.9 |
| 2. RO | 7.81 | 3.253 | 24.4 | 25.42 | 6.9 | 18.6 |
| 3. SE | 8.75 | 1.570 | 17.0 | 13.74 | 7.7 | 10.1 |
| 4. L | 6.41 | 1 493 | 16.6 | 9.57 | 5.6- | 7.0- |
| 5. WE | 8.45 | .978 | 13.4 | 8.25 | 7.4- | 6 1 |
| 6. YO | 1.80 | 4.094 | 27.4 | 7.36 | 1.5- | 5.4- |
| 7. WA | 3.05 | 2 260 | 20 4 | 6.88 | 2.7- | 5.0- |
| 8. BA | 2 73 | 2.352 | 20.8 | 6.43 | 2.4- | 4 7- |
| 9 H | 4.06 | 1 207 | 14.9 | 4.89 | 3.6 | 3.6 |
| 10. BO | 1.09 | 3.888 | 26.7 | 4.25 | 1.0 | 3.1 |
| 11. B | 6.25 | .270 | 7.0 | 1 69 | 5.5 | 1.2- |
| 12. BW | .55 | 2 879 | 23.0 | 1.57 | .5 | 1.2 |
| MINOR SPP. (9) | 2 73 | .528 | 9.8 | 1.44 | 2.4- | 1.1- |
| ALL SPP. (21) | 113.83 | 1 198 | 14.8 | 136.41 | 100.0 | 100.0 |

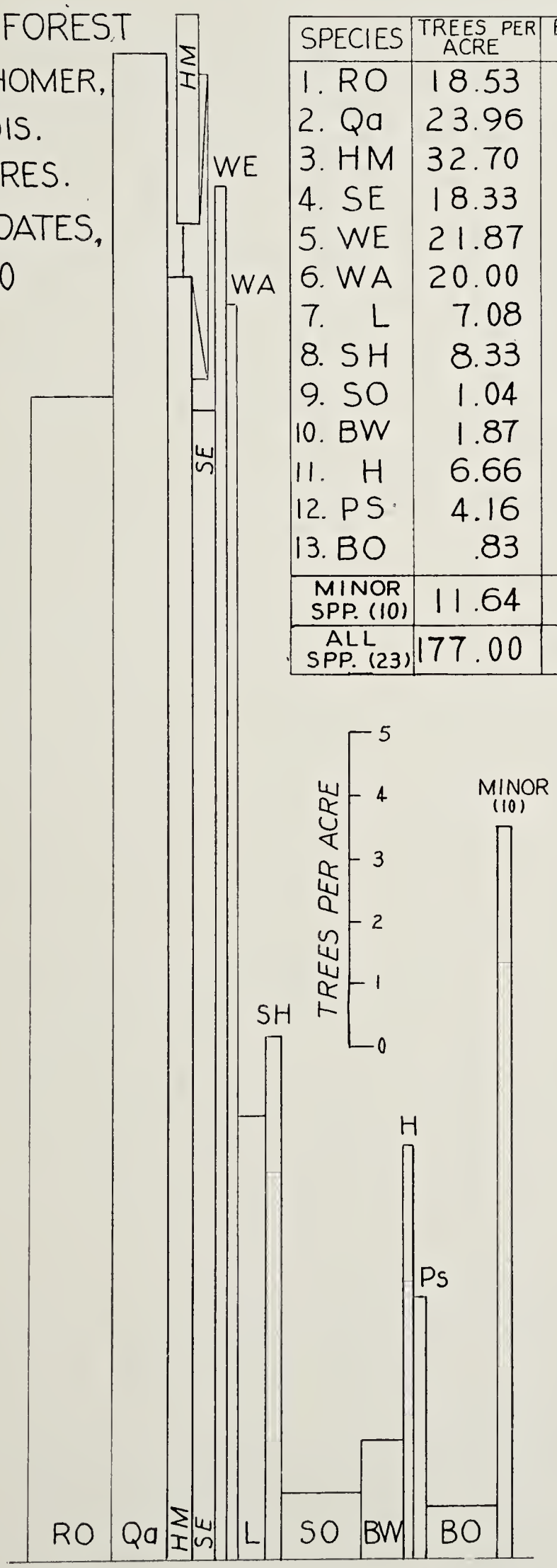
FIG. 3.—Same 16 plots 12 years later, 1951.

(black cherry) is now represented by one new tree. For all species, trees per acre are down from 126 to 114.

The other stand used for illustration is in the main timberbelt of Salt Fork, something over 20 miles downstream from Brownfield. It was surveyed in 1949-50 by James F. Coates. Its diagram (fig. 4) is strikingly different, in opposite direction from the last. It is tall and narrow, as are most of its bars for individual species. This obviously represents a stand of mostly smaller trees and higher density. This is due probably to poorer site and to a history of disturbance, including considerable cutting. It is rich in species, 23 of them in 4.8 acres. The east side is close to the edge of the stand, and includes several species not found in the interior. Species here that are not found in Brownfield are white oak (second in importance), and among minor species pignut hickory, black oak, sassafras, and boxelder.

Diagrams and tables such as these are only one of many devices for giving information about a forest. Many other types of summary, especially stand tables (which show the numbers of trees in successive diameter-classes) are also useful and for certain purposes more appropriate. However, composition diagrams and tables do present much significant information in a minimum of space, and do so in readily understandable form.

MIXED FOREST
NEAR HOMER,
ILLINOIS.
4.8 ACRES.
J. F. COATES,
1950




| SPECIES | TREES PER ACRE | B.A. PER TREE | D.B.H., AV. TREE | B.A. PER ACRE |
|---|---|---|---|---|
| 1. RO | 18.53 | 1.312 | 15.5 | 24.34 |
| 2. Qa | 23.96 | .868 | 12.6 | 20.81 |
| 3. HM | 32.70 | .417 | 8.8 | 13.64 |
| 4. SE | 18.33 | .352 | 8.0 | 6.46 |
| 5. WE | 21.87 | .201 | 6.1 | 4.39 |
| 6. WA | 20.00 | .182 | 5.8 | 3.63 |
| 7. L | 7.08 | .452 | 9.1 | 3.20 |
| 8. SH | 8.33 | .250 | 6.8 | 2.08 |
| 9. SO | 1.04 | 1.278 | 15.3 | 1.33 |
| 10. BW | 1.87 | .697 | 11.3 | 1.31 |
| 11. H | 6.66 | .160 | 5.4 | 1.04 |
| 12. PS | 4.16 | .204 | 6.1 | .85 |
| 13. BO | .83 | 1.015 | 13.6 | .85 |
| MINOR SPP. (10) | 11.64 | .249 | 6.8 | 2.91 |
| ALL SPP. (23) | 177.00 | .490 | 9.5 | 86.84 |

| SPP. | PER CENT OF STAND BY NO. | BY B.A. |
|---|---|---|
| 1. | 10.5 | 27.9 |
| 2. | 13.5 | 24.0 |
| 3. | 18.5 | 15.7 |
| 4. | 10.3 | 7.4 |
| 5. | 12.4 | 5.1 |
| 6. | 11.3 | 4.2 |
| 7. | 4.0 | 3.7 |
| 8. | 4.7 | 2.4 |
| 9. | .6 | 1.5 |
| 10. | 1.0 | 1.5 |
| 11. | 3.7 | 1.2 |
| 12. | 2.4 | 1.0 |
| 13. | .5 | 1.0 |
| MINOR | 6.6 | 3.4 |
| ALL | 100.0 | 100.0 |

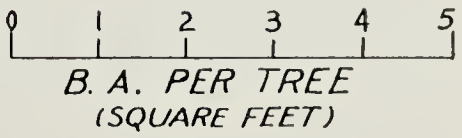



FIG. 4.—Diagram and table for 4.8 acres of upland mixed forest near Homer, 1950.

In a conversation following the presenting of this paper at the Macomb meeting, Dr. Leon S. Minckler stressed the desirability of supplementing the composition diagram by some form of graph showing diameter-distribution for the stand as a whole or for some of the principal species. If such a graph can be combined with or incorporated into the composition diagram, much more information can be shown. In any case, a stand table or stand graph can usually be supplied in addition.

One of the simplest and most compact forms of graph showing diameter distributions is that described in a probably little-known article by J. Paczoski (1928). His figures show a curve (apparently smoothed) for each species, indicating range and proportions of the different size-classes. Different kinds of line (solid, dashed, dotted, etc.) are used for different species. Not more than six or seven species can ordinarily be shown thus in a single compact figure, but more than one figure can be supplied.

A week later a letter and memorandum arrived from Dr. Minckler; he had experimented with diagrams for 21.8 acres of forest in southern Illinois. In these he superposed a line graph for the stand, showing diameter-distribution by one-inch classes. In one diagram he used, instead of basal area, cubic volume of average tree as the measure of size. Another measure he suggested is diameter of average tree; of the three measures, volume is closest to reality. In this same diagram Dr. Minckler used one of several possible ways of dividing the bar for a species into size-classes. He showed a narrow part for pole-sized trees (4.6 to 10.5-inch diam.) just atop a broader part for trees of saw-timber size (10.6-inch d.b.h. and larger). Thus white oak poles, 10 per acre, average 2.4 cu. ft. in volume. Larger white oaks, 5.5 per acre, average 20.7 cu. ft. per tree. The combined height of both parts of the bar is the same as if the species had not been divided into two size-classes. Another innovation was his printing of numerical values for volume directly at each bar in the diagram.

These experiments illustrate again the wide range of possible new ways of representing field counts and measurements graphically. It is hoped that Dr. Minckler and others will develop still other new forms of diagram.

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# DIAGRAMS TO SHOW WHICH SPECIES OCCUR IN PARTICULAR PLOTS OR STANDS

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*University of Illinois, Urbana*

The usual requirements in analyzing vegetation are met by ordinary summaries in tabular form: a column for each plot or stand, a line for each species. For some purposes, a diagram showing which species occur in each plot enables the reader to visualize the peculiarities of the different plots in a way that cannot be perceived from a table. In a simple geometric pattern of a few rows of circles, each species is assigned a particular position. The order is that of rank in abundance (or frequence, or bulk, or area covered, or percentage of presence in different stands).

The forest stand here used for illustration is a little larger than five acres on an upland close to the south bluff of Salt Fork of Vermilion River in eastern Champaign County, Illinois. It is 2.5 miles northwest of Homer and 3.8 miles northeast of Sidney. The bluff and the floodplain are generally tree-covered in this locality, which is known to nearby residents as Spencer Hole.

An area of 4.8 acres was surveyed in 1950 by James Franklin Coates of St. Joseph, Illinois. All trees three inches d.b.h. or larger were tallied separately for each tenth-acre plot (66 by 66 feet). The squares were contiguous in six rows, eight plots in each row. The area completely tallied is thus 396 by 528 feet. Among the several forms of summary in Coates' account of the stand (1951), he included grid maps of the area, each map divided into plots of a particular size (0.1, 0.2, 0.3, 0.4, 0.6, 0.8, 1.2, and 2.4 acres). On each plot is its diagram, with a circle for each species occurring there. The number in a circle shows how many trees of that species occur in that plot. Below the pattern of circles are three numbers. The upper number shows how many species are present; that at lower left is the sum of trees irrespective of species; at lower right is aggregate basal area for the plot (in square feet).

The first of four drawings here presented (fig.1) is the key to the pattern of positions for the 23 species, using their common names. They are arranged in order of abundance, the first three species having 157, 115, and 105 trees, the last six species represented by 3, 3, 2, 2, 1, and 1. Total number in 4.8 acres is 850; total basal area is 416.81 sq. ft. For another form of summary for the stand as a whole and for the 13 leading species, see the short paper in this same volume of the Academy's Transactions (Vestal, 1954).

Figure 2 is the basic tally for 16 tenth-acre plots, only one-third of the area, the southeastern part. In this and the remaining two figures, the top of the map is toward the east. Species present are identified by their positions.

Perhaps the outstanding fact, at once apparent, is the great difference

Figure 1

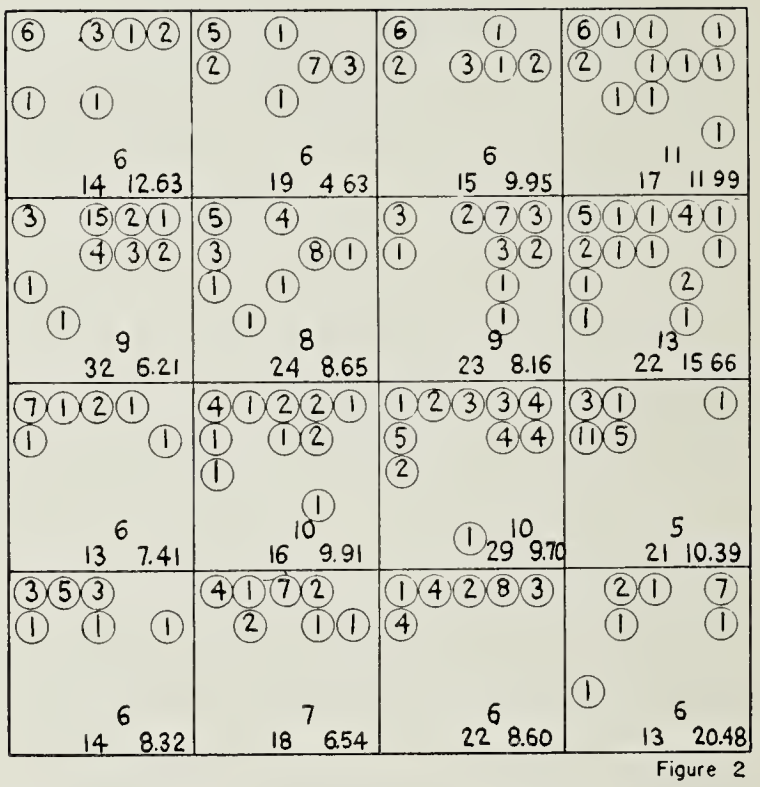


Figure 2

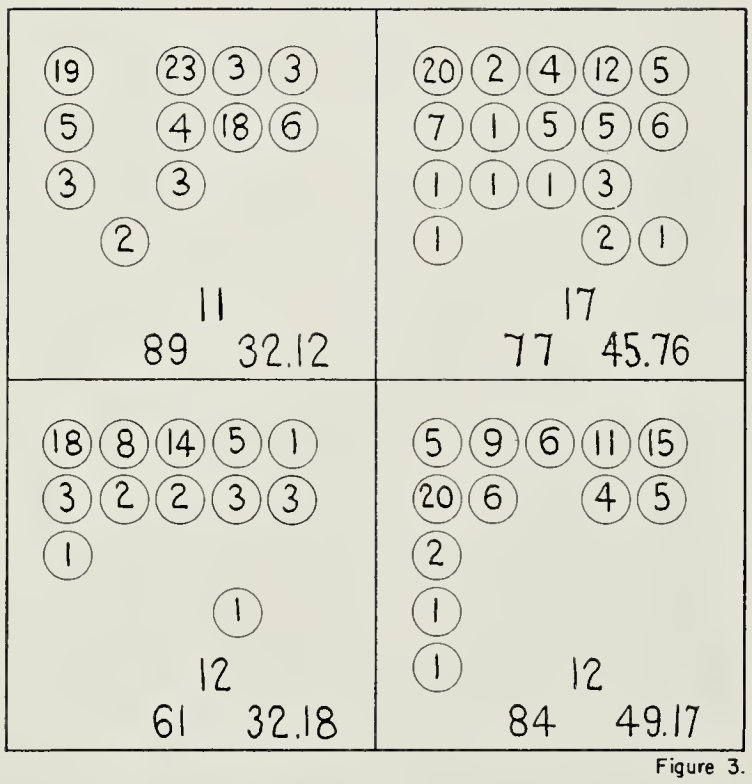


Figure 3.

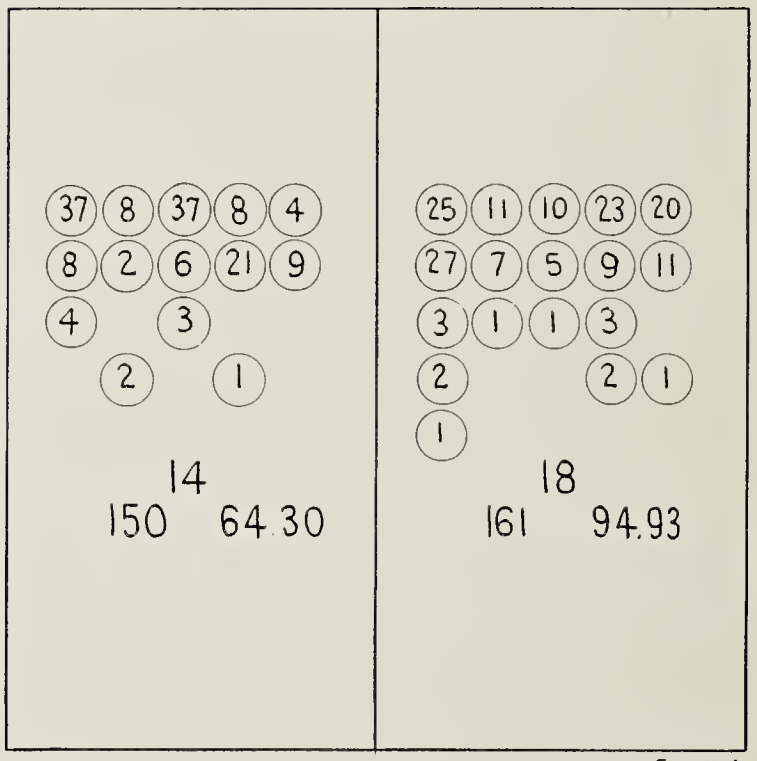


Figure 4.

FIGS. 1-4.—(1) Key to positions in the pattern for the 23 tree species. (2) (upper right) Grid map of southeast part of the stand: 16 plots, each 0.1 acre. (3) Same area: 4 plots, each 0.4 acre. (4) Same area: 2 plots, each 0.8 acre.

in composition in individual plots. Hardly ever in any one stand does one find two plots with the same combination of species. This is true in mixed forests, in bush, and in herbaceous vegetation of several types, as found by experience with numerous examples. It is true of small, large, and very large plot-sizes, and it is also true of whole stands. Even if the leading species should happen to be the same, as is true of Brownfield Woods and of Trelease Woods, a little over a mile apart, several minor species occur in one stand that are not found in the other. In the forest at Spencer Hole, two of the 48 tenth-acre plots do happen to contain the same species (only three, 1st, 2d, and 6th). These plots are north and northwest of the 16 plots shown in fig. 2.

This form of diagram makes it quickly evident whether the combinations of species in particular plots are widely different (the common situation) or closely similar. The more one studies details of composition, the more one is impressed with the complexity of a mixed all-aged forest, like many in eastern United States.

A little reflection on the mathematics of combinations shows how small is the probability that from among the many species available nearby, the particular selection which occurs in any one sample will be repeated in any other sample. In other words, if the average number of species per plot is 8 to 13 or more, as in this forest, the number of possible combinations of 4 or 8 or 12 species out of 20 or more becomes very large.

In Coates' study the patterns made it easy to discover that for the most part the two most abundant species occupy different parts of the stand. Hard maple has over 3 sq. ft. of basal area per plot in 11 of the tenth-acre plots in the east half, white oak in 12 plots in the west part.

Figure 3 shows plots four times as large as in the preceding grid-map. Again the individuality of plots is apparent. In Fig. 4 we see diagrams for two 0.8-acre plots. Individual plots may be compared with figures just below for a hypothetical average plot, using the whole area of 4.8 acres as the basis:

The method of using species-positions in a pattern was first used in 1936 to show which tree species in Trelease Woods were found in all plots of a set, and in different sets of plots. It was found that only four species were generally distributed within the stand, according to the test used. The diagrams which show this appear in the thesis of William Marberry (1936, pp. 28-29).

Grid-map summaries made up of plot diagrams, as well as their more familiar counterparts in tabular form, can be useful in the following types of study: (1) Ordinary presentations of data, as in descriptions of vegetation, (2) Inquiries into relative homogeneity or internal diversity of vegetation, (3) Studies to find which size of plot is most effective for a particular purpose, (4) Species and area (number of species in relation to extent of stand or sample), (5) Comparisons of plot-arrangements (contiguous vs. separated plots, etc.)

As to tabular arrays of plot data: for some purposes they are superior to the diagrams (e.g., in arranging data for coding for punch-card analysis). Both tables and diagrams can be very compact. The chief advantages of plot diagrams are their visual distinctiveness and the spatial orientation: each plot is correctly located in the stand and in relation to its neighbors. A table can give some visual distinctiveness, if each species is put in a column and if the columns

Average plot for each of three sizes:

| plot size | no. of species | no. of trees | aggregate b. a., sq. ft. |
|---|---|---|---|
| 0.1 acre | 8.0 | 17.7 | 8.68 |
| 0.4 acre | 13.0 | 70.8 | 34.73 |
| 0.8 acre | 15.5 | 141.7 | 69.47 |

are arranged in groups of 4 or 5 (corresponding to rows of circles in the diagrams).

Just as tables for plots within a stand, or association-tables for a number of different stands, can be modified according to the kinds of information shown, so grid-maps made up of diagrams of plots can be modified. Many variations will suggest themselves as to kinds of data which can be shown and as to modes of showing them. The method can be adapted also to kinds of vegetation other than forest.

It is appropriate to express my appreciation to Mr. Coates for use of his findings, which are detailed and complete over a one-piece area much larger than is available in most sets of data.

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# FLORA AND ECOLOGICAL ANALYSIS OF THE VEGETATION OF THE FUNK FOREST NATURAL AREA, McLEAN COUNTY, ILLINOIS

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## Introduction

The purposes of this investigation were (1) to compile a list of vascular plants and (2) to analyze the vegetation of the Funk Forest Natural Area. This newest acquisition to the University of Illinois preserves is in the east-central part of Illinois, about fifteen miles southwest of Bloomington, between the towns of Funks Grove and McLean (fig. 1). It is off U. S. Highway 66 in the southeast corner of Section 19, Funk's Grove Township, McLean County.

The Funk Forest Natural Area was presented to the University of

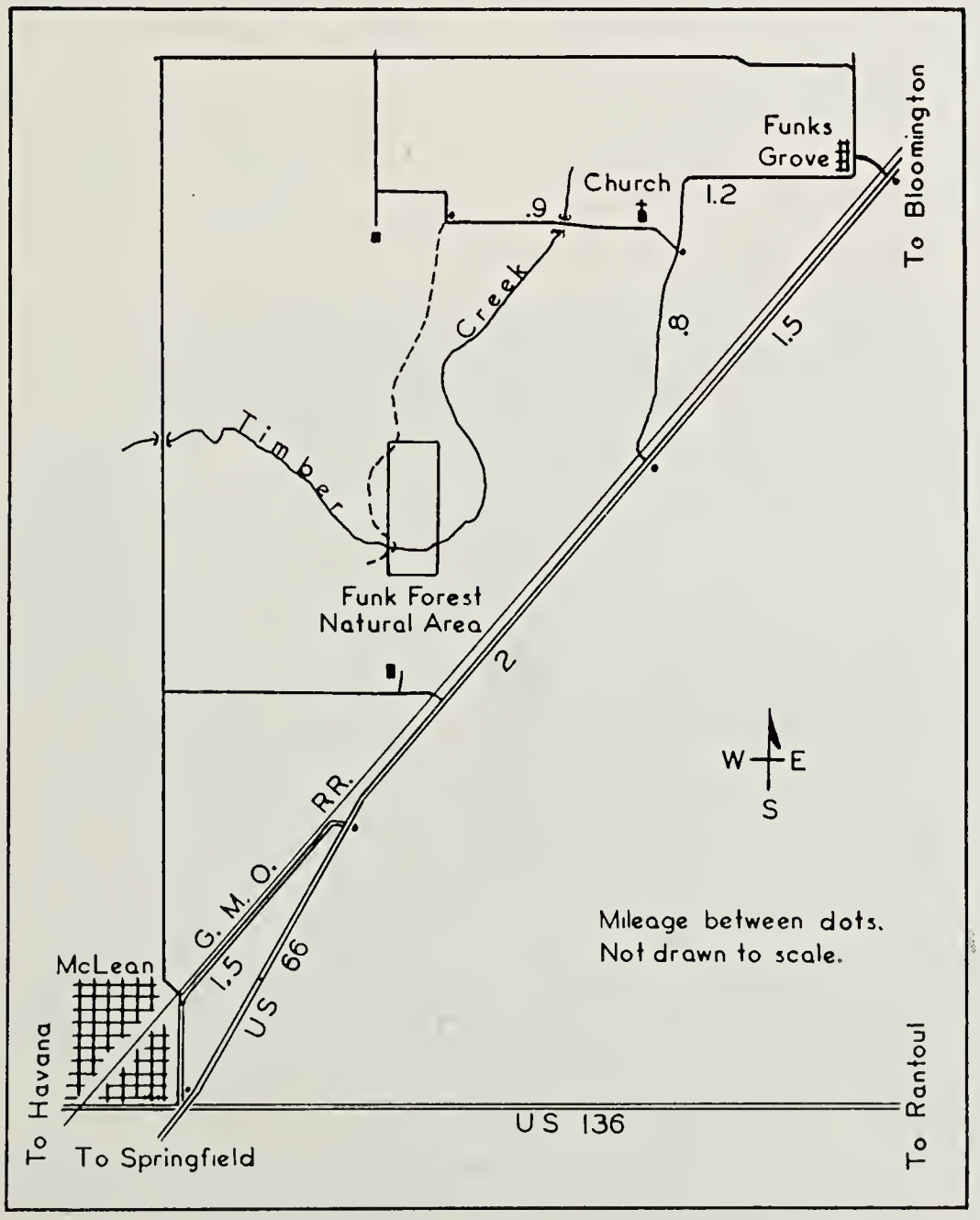


Fig. 1.—Location of the Funk Forest Natural Area.

Illinois, February 19, 1950, by the great-grandchildren of pioneer Isaac Funk. He settled at Funks Grove in 1824 and by 1863 he had purchased nearly 25,000 acres of land (Cavanagh, 1952). This portion of his original estate has been preserved since it was acquired in 1833. Thus, the tract now stands as a sample of prairie grove timber that has been fairly well preserved. It is to be used for scientific investigations of its plant and animal life and of its soil conditions.

The tract is about 2625 feet long and 1039 feet wide, an area of approximately 63 acres. Surrounding land was identified as slash timber, second-growth timber, brushy forest edge, grassy bottomland, pastured grassland, cleared pastured woodland, and uncleared pastured woodland (fig. 2). Evidence of cultural disturbance within the preserve consisted of stumps and logs from a small amount of felled timber, logging wagon trails, refuse dumps, cattle trails and grazing.

## Methods

This study began February 25, 1950, and ended November 1, 1951. Field trips were made biweekly in spring and summer seasons, weekly in autumn, and bimonthly in winter. The study area was divided into 50-meter square quadrats using a coordinate system (fig. 3). The base line, from which transect lines extended at right angles, coincided with the surveyor's north boundary line. A cornerstone at the northeast corner was the zero-point. Lath stakes marked quadrat corners. A tree nearest each corner was posted

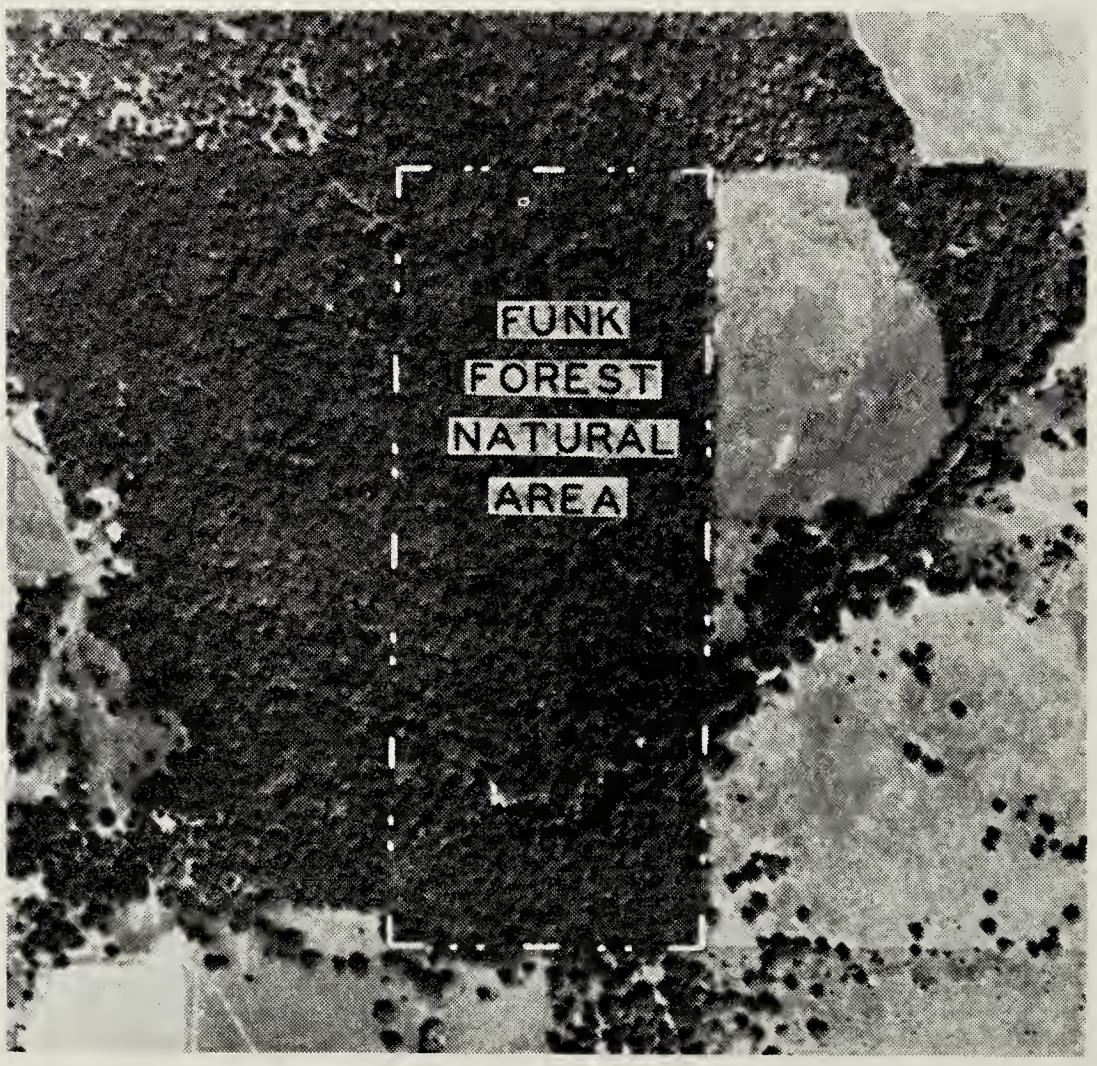


Fig. 2.—Aerial photograph of the Funk Forest Natural Area (U.S.D.A. X-5A-132, July 6, 1940).

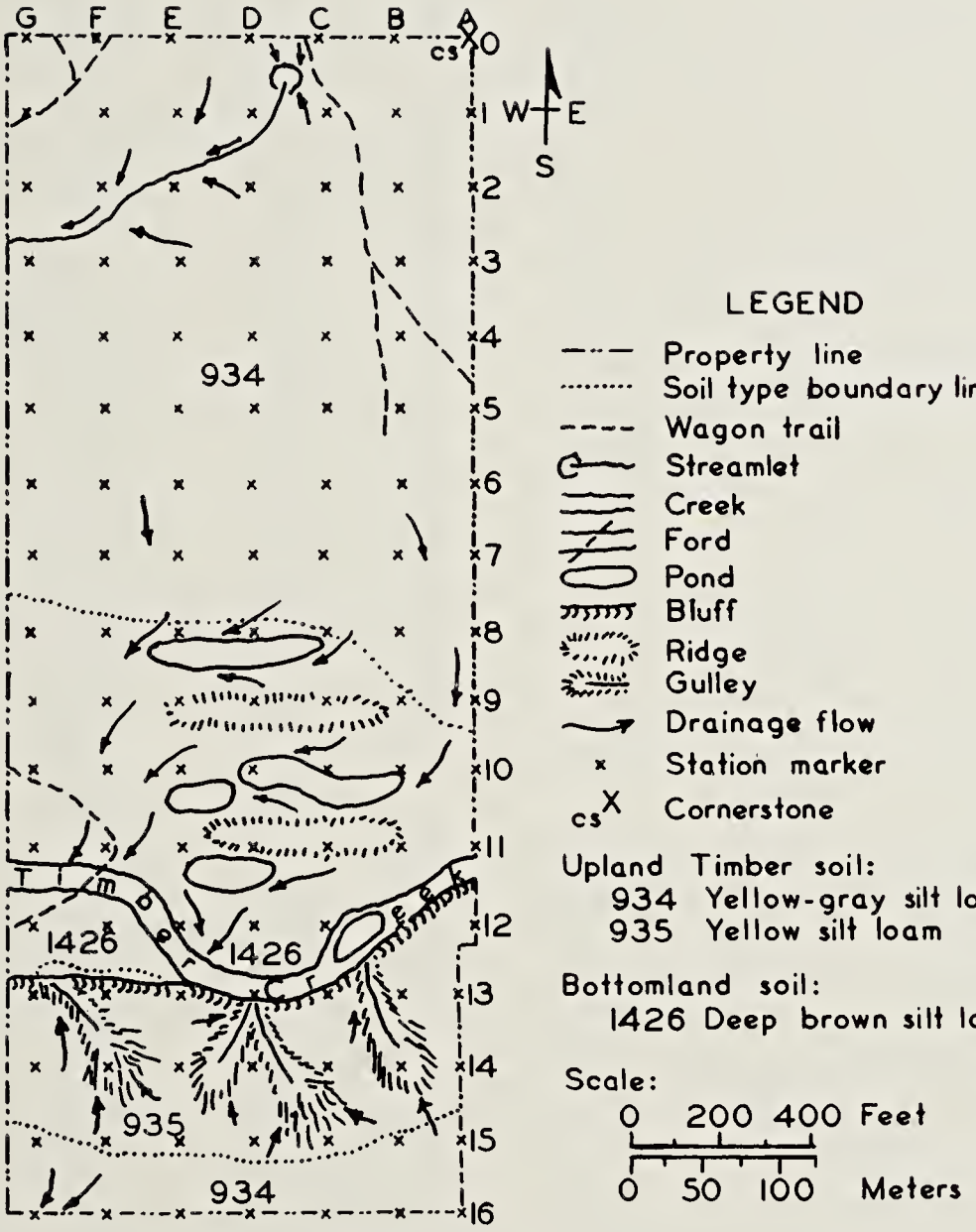


FIG. 3.—Field map of the study area.

with two types of markers. One was a small wooden nursery tag bearing the station reference number. The other consisted of a set of four yellow oilcloth tags, 3 by 5 inches, to provide for optimum visibility. Station reference numbers were marked on the oilcloth with black china-marking pencil. The tags were placed about six feet high at four points on the tree trunk where they were visible along north-south and east-west grid lines.

The species of vascular plants recorded in the checklist were chiefly collected within the study area. All identifications were verified by Harry E. Ahles, assistant in the Herbarium of the University of Illinois. One or more specimens of each species is deposited in the Herbarium. Reports of species not based upon specimens have been omitted. Nomenclature is based upon Jones (1950).

The floral composition of the Funk Forest Natural Area was compared with records available through 1951 for other University of Illinois woodland preserves. Data for Robert Allerton Park were taken from unpublished records (Jones, ms.). Data for the University of Illinois Woodlands, which includes Brownfield Woods and Trelease Woods, were obtained from Jones (1947). The dis-

tribution of each species is indicated by appropriate symbols in the checklist.

Methods for analysis of the dominant vegetation were based upon Chapman and Meyer (1949) and Guise (1950). The strip method was used, in which cruises were made along five strips 33 feet wide and 2625 feet long. Each strip was laid out at right angles to the base line at Stations A-O, B-O, D-O, F-O and G-O (fig. 4). This area amounted to 9.9 acres, a 15.8 percent sample. All stems three inches and greater d.b.h. were identified and measured with a tree diameter tape.

Identifications for Raunkiaer's life-form classification were based on field observations, phenological records, and collections of specimens in various developmental stages. Information for the classification of grasses was obtained from Deam (1929) and Hitchcock (1950). Sources for identification of structures were Britton and Brown (1923), DuRietz (1931) and Fernald (1950). Classifications are given in the checklist only for species collected within the study area.

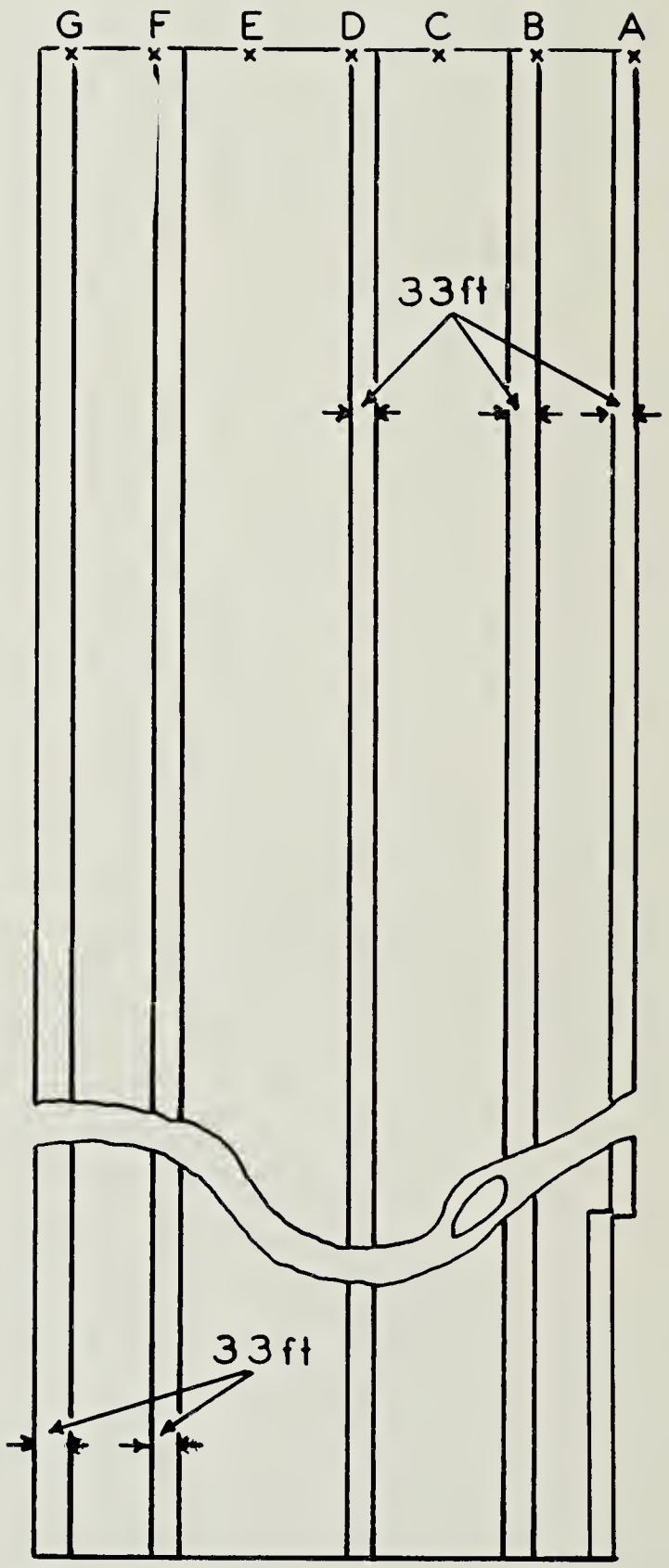


Fig. 4.—Location of five cruise strips for the tree survey.

## Physical Environment

The Funk Forest Natural Area is in the Till Plains section of the Central Lowland physiographic province (Fenneman, 1928). The soils have been influenced primarily by Early Wisconsin glaciation. A deposit of loess covers the Leroy moraine that underlies this area (Hopkins, et al., 1915). Within the study area are found upland timber and bottomland types of soil (fig. 3). One class of upland timber soil, yellow-gray silt loam, occurs as a part of the southern margin and again in the northern end. A second class, yellow silt loam, occurs only along the south bank of Timber Creek where a high bluff has been formed. Bottomland soil, deep brown silt loam, covers the lowland north of Timber Creek. The creek bottom is varied; part is smooth clay from bluff outcrops, others sandy or strewn with rocks and boulders.

The highest elevation is 690 feet. The lowest point is about 640 feet. Areas of greatest local relief are along the deeply eroded bluff where places are as high as 40 feet above the creek bed. The slight relief in the bottomland appears as a series of three roughly concentric depressions ranging in depth from a few inches to about three feet (fig. 3). Timber Creek averages about 35 feet wide, and it is five to six feet below the north bank. The main stream is divided near the eastern margin to form an island 153 feet long and 55 feet wide. Water flows westward and there are pools that vary in depth from five to ten feet.

Drainage patterns (fig. 3) are based on field observations. Timber Creek is the principal outlet for springs that flow out of the bluff over the clay outcrops and for surface runoff. Water from thaws and floods drains through gullies cut into the banks. After overflows have receded, water stands in the depressions until it evaporates and seeps away. These semi-permanent woodland ponds become stagnant and usually do not dry until late July. A second minor outlet is a small streamlet in the northern end of the tract. Water that collects in a shallow temporary pond at the head of the streamlet during spring is discharged onto a broad flat in the slash timberland beyond the western boundary of the tract.

## Local Climate

Weather data (table 1) were obtained from the U. S. Weather Station at Normal, Illinois, 15 miles northeast of the Funk Forest Natural Area (Climatological Data, 1950 and 1951). The annual mean temperature was about 51°F. each year. High temperatures came in July and lows in December. In 1950, precipitation was above normal with the greatest amount in June and the least in March. In 1951, it was near

Table 1.—Average Monthly Temperatures, Total Monthly Precipitation, and Departures from Normal, 1950 and 1951

| Mos. | Temperature, °F | | | | Precipitation, Inches | | | |
|---|---|---|---|---|---|---|---|---|
| | 1950 | | 1951 | | 1950 | | 1951 | |
| | Monthly Average | Departure | Monthly Average | Departure | Monthly Total | Departure | Monthly Total | Departure |
| Jan | 33.0 | 6.8 | 27.9 | 1.7 | 5.31 | 3.21 | 1.51 | –0.59 |
| Feb | 29.1 | 0.4 | 30.6 | 1.9 | 3.62 | 1.87 | 3.98 | 2.23 |
| Mar | 37.0 | –3.3 | 37.1 | –3.2 | 0.75 | –2.40 | 3.61 | 0.46 |
| Apr | 45.9 | –5.6 | 49.1 | –2.4 | 6.51 | 2.97 | 3.45 | –0.09 |
| May | 64.9 | 2.3 | 65.6 | 3.0 | 1.38 | –2.78 | 2.81 | –1.35 |
| June | 71.7 | –0.2 | 69.5 | –2.4 | 7.02 | 2.91 | 5.35 | 1.24 |
| July | 73.7 | –3.4 | 74.9 | –1.6 | 3.37 | 0.30 | 3.37 | 0.30 |
| Aug | 70.6 | –3.7 | 72.6 | –1.7 | 0.97 | –2.51 | 3.51 | 0.03 |
| Sep | 66.8 | –0.5 | 65.0 | –2.3 | 4.21 | 0.22 | 1.11 | –2.88 |
| Oct | 61.6 | 6.4 | 58.4 | 3.2 | 1.60 | –1.21 | 2.22 | –0.59 |
| Nov | 36.3 | –5.3 | 34.9 | –6.7 | 2.37 | –0.31 | 3.24 | 0.56 |
| Dec | 21.7 | –7.6 | 27.9 | –1.4 | 1.04 | –0.59 | 2.01 | 0.05 |

normal with the greatest amount in June and the least in September. First and last snowfalls came November 20, 1949, and April 5, 1950; and November 2, 1950, and April 12, 1951. Daily maximum sunshine in summer was fifteen hours, and in winter it was nine hours. The sun was at its highest latitude June 21, while peak temperatures were later in mid-July.

In 1950, the last killing frost in spring was April 28, and the first in autumn was November 5. In 1951, they were on April 23 and November 1. Normal dates are April 27 and October 16. Length of time free from frost was about 190 days. Since 172 days is normal, with a range from 168 to 190 days (Page, 1949), the growing season for these two years averaged 18 days longer than normal.

Winds prevailed from the west and northwest. In summer they were more frequently southwesterly, but in winter they were northwesterly. Sudden changes in wind direction usually affected conditions of temperature and precipitation.

## Checklist of Vascular Plants

The checklist of vascular plants includes 213 species in 148 genera and 69 families. Four plant names are excluded from the data for forthcoming discussions. They are the two species, osage orange, *Maclura pomifera*, and dwarf larkspur, *Delphinium tricorne*, which were collected in the border outside of the study area; and the two forms, spineless honey locust, *Gleditsia triacanthos* f. *inermis*, and white bluebells, *Mertensia virginica* f. *Berdi*.

The species that were recorded for the Funk Forest Natural Area were compared with records for two other University of Illinois preserves. Twenty-five (11.9%) of the species are recorded only for the Funk Forest Natural Area. Twenty-nine (13.7%) were also recorded for the University of Illinois Woodlands, which includes Brownfield Woods and Trelease Woods. Thirty-seven (17.5%) were also recorded for Robert Allerton Park. One hundred and twenty (56.9%) were recorded for all the preserves.

### DIVISION I. PTERIDOPHYTA. FERNS AND FERN ALLIES

#### Equisetaceae Michx.—Horsetail Family

*Equisetum arvense* L., field horsetail. A.[1]

#### Ophioglossaceae Presl—Adder's-tongue Family

*Botrychium virginianum* (L.) Sw., rattlesnake fern. U.[2]

#### Polypodiaceae R.Br.—Fern Family

*Adiantum pedatum* L., maidenhair fern. A.

*Cystopteris fragilis* (L.) Bernh., brittle fern. A. U.

*Onoclea sensibilis* L., sensitive fern. A.

*Polystichum acrostichoides* (Michx.) Schott, Christmas fern. A.

### DIVISION II. SPERMATOPHYTA. SEED PLANTS

#### Subdivision II. Angiospermae. Flowering Plants

#### Class I. Monocotyledoneae

#### Gramineae Juss.—Grass Family

*Bromus latiglumis* (Shear) Hitchc., brome grass. H.[3]

*Echinochloa crusgali* (L.) Beauv., barnyard grass. Th.[3] A. U.

*Elymus villosus* Muhl., slender wild rye. H. A.

*Elymus virginicus* L., wild rye. H. A.

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[1] Robert Allerton Park.
[2] University of Illinois Woodlands.
[3] Raunkiaer life-form class: Chamaephytes (Ch); Cryptophytes (Cr); Hemicryptophytes (H); Phanerophytes (Ph); and Therophytes (Th).

*Glyceria striata* (Lam.) Hitchc., manna grass. H. U.
*Hystrix patula* Moench, bottlebrush grass. H.
*Panicum dichotomiflorum* Michx., spreading witch grass. Th. U.
*Poa sylvestris* A. Gray, woodland blue grass. H. A.

CYPERACEAE J. St. Hil.—Sedge Family

*Carex albursina* Sheldon. H. U.
*Carex hirtifolia* Mack. Cr. U.
*Carex jamesii* Schw. H.
*Carex pennsylvanica* Lam. Cr.
*Carex rosea* Schk. H. A. U.
*Carex shortiana* Dewey. H.
*Carex sparganioides* Muhl. Cr.

ARACEAE Necker—Arum Family

*Arisaema dracontium* (L.) Schott, green dragon. Cr. A. U.
*Arisaema triphyllum* (L.) Schott, jack-in-the-pulpit. Cr. A. U.

COMMELINACEAE Reinchenb.—Spiderwort Family

*Tradescantia subaspera* Ker., zigzag spiderwort. H. A. U.
*Tradescantia virginiana* L., spiderwort. H. A.

LILIACEAE Adans.—Lily Family

*Allium canadense* L., wild garlic. Cr. A. U.
*Allium tricoccum* Ait., wild leek. Cr. A. U.
*Erythronium albidum* Nutt., white trout lily. Cr. A. U.
*Lilium michiganense* Farw., turk's-cap lily. Cr. U.
*Polygonatum commutatum* (Schult.) Dietr., Solomon's-seal. Cr. A.
*Polygonatum pubescens* (Willd.) Pursh, small Solomon's-seal. Cr. U.
*Smilacina racemosa* (L.) Desf., large false Solomon's-seal. Cr. A. U.
*Smilacina stellata* (L.) Desf., small false Solomon's-seal. Cr. A. U.
*Smilax ecirrhata* (Engelm.) Wats., upright smilax. Cr. A. U.
*Smilax hispida* Muhl., common greenbrier. Ph. A. U.
*Smilax lasioneura* Hook., carrion flower. Cr. A. U.
*Trillium gleasoni* Fern., Gleason's trillium. Cr. A. U.
*Trillium nivale* Riddell, snow trillium. Cr. A.
*Trillium recurvatum* Beck, purple trillium. Cr. A. U.
*Uvularia grandiflora* Sm., bellwort. Cr. A. U.
*Veratrum woodii* Robbins., Wood's false hellebore. Cr.

DIOSCOREACEAE Lindl.—Yam Family

*Dioscorea villosa* L., yam. Cr.

ORCHIDACEAE Lindl.—Orchid Family

*Aplectrum hyemale* (Muhl.) Torr., putty-root. Cr. U.

Class II. Dicotyledoneae Juss.

SALICACEAE Lindl.—Willow Family

*Salix nigra* Marsh., black willow. Ph. A.

JUGLANDACEAE Lindl.—Walnut Family

*Carya cordiformis* (Wang.) K. Koch, bitternut hickory. Ph. A. U.
*Carya ovalis* (Wang.) Sarg., false shagbark Hickory. Ph.
*Carya ovata* (Mill.) K. Koch, shagbark hickory. Ph. U.
*Carya tomentosa* Nutt., mockernut Hickory. Ph. A.
*Juglans cinerea* L., butternut. Ph. U.
*Juglans nigra* L., black walnut. Ph. A. U.

BETULACEAE Agardh.—Birch Family

*Carpinus caroliniana* Walt., blue beech. Ph. A. U.
*Ostrya virginiana* (Mill.) K. Koch., hop-hornbeam. Ph. A. U.

FAGACEAE A. Br.—Beech Family

*Quercus alba* L., white oak. Ph. A.
X *Quercus fallax* E. J. Palmer (Q. *macrocarpa* X Q. *muhlenbergii*). Ph.
*Quercus macrocarpa* Michx., bur oak. Ph. A. U.
*Quercus muhlenbergii* Engelm., chinquapin oak. Ph. U.
*Quercus rubra* L., red oak. Ph. A. U.
*Quercus velutina* Lam., black oak. Ph. A. U.

ULMACEAE Mirb.—Elm Family

*Celtis occidentalis* L., hackberry. Ph. A. U.
*Ulmus americana* L., American elm. Ph. A. U.
*Ulmus rubra* Muhl., slippery elm. Ph. A. U.

MORACEAE Lindl.—Mulberry Family

*Maclura pomifera* (Raf.) Schneid., osage orange. (Outside southeast corner.)
*Morus rubra* L., red mulberry. Ph. U.

URTICACEAE Reichenb.—Nettle Family

*Laportea canadensis* (L.) Gaud., wood nettle. Cr. A. U.
*Urtica dioica* L., great nettle. H.

ARISTOLOCHIACEAE Blume—Birthwort Family

*Asarum reflexum* Bickn., wild ginger. H. A. U.

POLYGONACEAE LINDL.—BUCKWHEAT FAMILY

*Polygonum convolvulus* L., black bindweed. Th. A.
*Polygonum hydropiper* L., water-pepper. Th.
*Polygonum pennsylvanicum* L., Pennsylvania smartweed. Th. A. U.
*Polygonum virginianum* L., Virginia knotweed. Cr. A. U.
*Rumex altissimus* Wood, pale dock. H.

PHYTOLACCACEAE LINDL.—POKEWEED FAMILY

*Phytolacca americana* L., Pokeweed. Cr. A. U.

PORTULACACEAE REICHENB.—PURSLANE FAMILY

*Claytonia virginica* L., spring beauty. Cr. A. U.

CARYOPHYLLACEAE REICHENB.—PINK FAMILY

*Cerastium vulgatum* L., common mouse-ear chickweed. Ch. A. U.
*Silene stellata* (L.) Ait. f., starry catchfly. H. A. U.

ANNONACEAE DC.—CUSTARD-APPLE FAMILY

*Asimina triloba* (L.) Dunal., pawpaw. Ph. A. U.

RANNUNCULACEAE JUSS.—BUTTERCUP FAMILY

*Actaea alba* (L.) Mill., white baneberry. Cr. A. U.
*Delphinium tricorne* Michx., dwarf larkspur. (Outside western margin.)
*Hepatica acutiloba* DC, sharp-lobed hepatica. H. A. U.
*Hydrastis canadensis* L., goldenseal. Cr. U.
*Isopyrum biternatum* (Raf.) T. & G., false rue-anemone. H. A. U.
*Ranunculus abortivus* L., small-flowered buttercup. H. A. U.
*Ranunculus hispidus* Michx., bristly buttercup. H.
*Ranunculus septentrionalis* Poir., marsh buttercup. H. A. U.
*Thalictrum dasycarpum* Fisch. & Lall., purplish meadow-rue. H.
*Thalictrum revolutum* DC., waxy meadow-rue. H. A. U.

MENISPERMACEAE DC.—MOONSEED FAMILY

*Menispermum canadense* L., moonseed. Ch. A. U.

BERBERIDACEAE T. & G.—BARBERRY FAMILY

*Caulophyllum thalictroides* (L.) Michx., blue cohosh. Cr. U.
*Podophyllum peltatum* L., mayapple. Cr. A. U.

PAPAVERACEAE B. JUSS.—POPPY FAMILY

*Sanguinaria canadensis* L., bloodroot. Cr. A. U.

FUMARIACEAE DC.—FUMITORY FAMILY

*Dicentra canadensis* (Goldie) Walp., squirrel-corn. Cr. A. U.
*Dicentra cucullaria* (L.) Bernh., dutchman's-breeches. Cr. A. U.

CRUCIFERAE B. JUSS.—MUSTARD FAMILY

*Arabis dentata* T. & G., Rockcress. H. A.
*Arabis lævigata* (Muhl.) Poir., smooth rockcress. H. A.
*Barbarea vulgaris* R. Br., common wintercress. H. A. U.
*Capsella bursa-pastoris* (L.) Medic., shepherd's purse. Th. A. U.
*Dentaria laciniata* Muhl., toothwort. Cr. A. U.
*Iodanthus pinnatifidus* (Michx.) Steud., purple rocket. H. A. U.
*Rorippa sessiliflora* (Nutt.) Greene, yellow cress. H.

CRASSULACEAE DC.—STONECROP FAMILY

*Penthorum sedoides* L., ditch stonecrop. H.

GROSSULARIACEAE DUM.—GOOSEBERRY FAMILY

*Ribes missouriense* Nutt., common gooseberry. Ph. A. U.

PLATANACEAE LINDL.—PLANE-TREE FAMILY

*Platanus occidentalis* L., sycamore. Ph. A. U.

ROSACEAE B. JUSS.—ROSE FAMILY

*Crataegus margaretta* Ashe, Brown's thorn. Ph. A.
*Crataegus mollis* (T. & G.) Scheele, downy thorn. Ph. A. U.
*Geum canadense* Jacq., white avens. H. U.
*Potentilla monspeliensis* L., rough cinquefoil. H. U.
*Potentilla recta* L., rough-fruited cinquefoil. H. A.
*Prunus serotina* Ehrh., wild black cherry. Ph. A. U.
*Rubus allegheniensis* Porter, Allegheny blackberry. H. A.
*Rubus occidentalis* L., black raspberry. H. A. U.

LEGUMINOSAE JUSS.—PEA FAMILY

*Amphicarpa comosa* (L.) G. Don, hog peanut. H.
*Cercis canadensis* L., redbud. Ph. A. U.
*Desmodium glutinosum* (Muhl.) Wood, tick-clover. H. A. U.
*Gleditsia triacanthos* L., honey locust. Ph. A. U.
*Gleditsia triacanthos* L. f. *inermis* (Moench) C. K. Schneid.
*Gymnocladus dioica* (L.) K. Koch, Kentucky coffee-tree. Ph. A. U.
*Melilotus alba* Desr., white sweet clover. H. A.
*Trifolium pratense* L., red clover. H. A. U.

GERANIACEAE J. ST. HIL.—GERANIUM FAMILY

*Geranium maculatum* L., wild geranium. H. A. U.

OXALIDACEAE LINDL.—WOOD-SORREL FAMILY

*Oxalis cymosa* Small, common wood-sorrel. H. A. U.

BALSAMINACEAE LINDL.—JEWEL-WEED FAMILY

*Impatiens biflora* Walt., spotted touch-me-not. Th. A. U.
*Impatiens pallida* Nutt., pale touch-me-not. Th. A. U.

LIMNANTHACEAE LINDL.—LIMNANTHES FAMILY

*Floerkea proserpinacoides* Willd., false mermaid. Th. A. U.

RUTACEAE JUSS.—RUE FAMILY

*Ptelea trifoliata* L., hop-tree. Ph. A.
*Zanthoxylum americanum* Mill., prickly-ash. Ph. A. U.

CELASTRACEAE LINDL.—STAFF-TREE FAMILY

*Euonymus atropurpureus* Jacq., wahoo. Ph. A. U.

STAPHYLEACEAE DC.—BLADDERNUT FAMILY

*Staphylea trifolia* L., American bladdernut. Ph. A. U.

ANACARDIACEAE LINDL.—SUMAC FAMILY

*Rhus radicans* L., poison ivy. Ph. A. U.

ACERACEAE LINDL.—MAPLE FAMILY

*Acer negundo* L., box elder. Ph. A. U.
*Acer nigrum* Michx. f., black maple. Ph. U.
*Acer saccharinum* L., silver maple. Ph. A. U.
*Acer saccharum* Marsh., sugar maple. Ph. A. U.

VITACEAE LINDL.—GRAPE FAMILY

*Parthenocissus quinquefolia* (L.) Planch., Virginia creeper. Ph. A. U.
*Vitis aestivalis* Michx., summer grape. Ph.
*Vitis riparia* Michx., riverbank grape. Ph. A.

TILIACEAE JUSS.—LINDEN FAMILY

*Tilia americana* L., American linden. Ph. A. U.

VIOLACEAE DC.—VIOLET FAMILY

*Viola eriocarpa* Schw., common yellow violet. H. A. U.
*Viola papilionacea* Pursh., butterfly violet. H. A. U.
*Viola sororia* Willd., downy blue violet. H. A. U.

CUCURBITACEAE B. JUSS.—GOURD FAMILY

*Sicyos angulata* L., bur-cucumber. Th. A.

ONAGRACEAE DUM.—EVENING-PRIMROSE FAMILY

*Circaea latifolia* Hill, enchanter's-nightshade. Cr. A. U.
*Oenothera biennis* L., common evening-primrose. H. A. U.

CORNACEAE LINK—DOGWOOD FAMILY

*Cornus racemosa* Lam., gray dogwood. Ph. A. U.

ARALIACEAE VENT.—GINSENG FAMILY

*Aralia racemosa* L., American spikenard. H.
*Panax quinquefolius* L., ginseng. Cr. A. U.

UMBELLIFERAE B. JUSS.—PARSLEY FAMILY

*Cryptotaenia canadensis* (L.) DC., honewort. H. A. U.
*Erigenia bulbosa* (Michx.) Nutt., harbinger-of-spring. Cr. A.
*Heracleum lanatum* Michx., cow-parsnip. Cr. A.
*Osmorhiza claytoni* (Michx.) Clarke, hairy sweet cicely. H. A. U.
*Osmorhiza longistylis* (Torr.) DC., sweet cicely. H. A. U.
*Pastinaca sativa* L., parsnip. H. A. U.
*Perideridia americana* (Nutt.) Reichenb. Cr. A.
*Sanicula canadensis* L., sanicula. H. U.
*Sanicula gregaria* Bickn., clustered snakeroot. H. A.

PRIMULACEAE VENT.—PRIMROSE FAMILY

*Lysimachia ciliata* L., fringed loosestrife. H. U.

OLEACEAE LINDL.—OLIVE FAMILY

*Fraxinus americana* L., white ash. Ph. A. U.
*Fraxinus lanceolata* Borkh., green ash. Ph. U.
*Fraxinus quadrangulata* Michx., blue ash. Ph. U.

ASCLEPIADACEAE LINDL.—MILKWEED FAMILY

*Asclepias syriaca* L., common milkweed. Cr. A. U.

CONVOLVULACEAE VENT.—MORNING-GLORY FAMILY

*Ipomoea hederacea* Jacq., ivy-leaved morning-glory. Th. U.

POLEMONIACEAE DC.—PHLOX FAMILY

*Phlox divaricata* L., blue phlox. Ch. A. U.

HYDROPHYLLACEAE LINDL.—WATERLEAF FAMILY

*Ellisia nyctelea* L., nyctelea. Th. A. U.
*Hydrophyllum appendiculatum* Michx., waterleaf. H. A. U.
*Hydrophyllum canadense* L., Canada waterleaf. Cr. A. U.
*Hydrophyllum virginianum* L., Virginia waterleaf. H. A. U.

BORAGINACEAE LINDL.—BORAGE FAMILY

*Mertensia virginica* (L.) Pers., bluebells. H. A. U.
*Mertensia virginica* (L.) Pers. f. *Berdi* Moldenke, white bluebells.

VERBENACEAE J. ST. HIL.—VERBENA FAMILY

*Verbena stricta* Vent., hoary vervain. H. A.

LABIATAE B. JUSS.—MINT FAMILY

*Agastache nepetoides* (L.) Ktze, giant hyssop. H. A. U.
*Agastache scrophulariaefolia* (Willd.) Ktze, figwort giant hyssop. H. A.
*Blephilia hirsuta* (Pursh) Benth., hairy blephilia. H. A. U.
*Leonurus cardiaca* L., motherwort. H. A. U.
*Monarda fistulosa* L., bergamot mint. H. A.
*Prunella vulgaris* L., selfheal. H. A. U.

SCROPHULARIACEAE LINDL.—FIGWORT FAMILY

*Collinsia verna* Nutt., blue-eyed mary. H. A. U.
*Mimulus ringens* L., monkey flower. H. U.
*Scrophularia lanceolata* Pursh, figwort. H. A.
*Veronica arvensis* L., corn speedwell. Th. U.
*Veronica connata* Raf., speedwell. Ch.
*Veronica peregrina* L., purslane speedwell. Th. U.

ACANTHACEAE J. ST. HIL.—ACANTHUS FAMILY

*Ruellia strepens* L., smooth ruellia. Cr. A. U.

PHRYMACEAE SCHAUER—LOPSEED FAMILY

*Phryma leptostachya* L., lopseed. H. A. U.

PLANTAGINACEAE LINDL.—PLANTAIN FAMILY

*Plantago rugellii* Dcne., common plantain. H. A. U.

RUBIACEAE B. JUSS.—MADDER FAMILY

*Galium aparine* L., goose-grass. Th. A. U.
*Galium circaezans* Michx., wild licorice. H.
*Galium concinnum* T. & G., bedstraw. H. U.
*Galium triflorum* Michx., sweet-scented bedstraw. H. A.

CAPRIFOLIACEAE VENT.—HONEYSUCKLE FAMILY

*Sambucus canadensis* L., common elder. Ph. A. U.
*Viburnum prunifolium* L., blackhaw. Ph. A. U.

CAMPANULACEAE JUSS.—BELLFLOWER FAMILY

*Campanula americana* L., bellflower. H. A. U.

LOBELIACEAE DUM.—LOBELIA FAMILY

*Lobelia siphilitica* L., great lobelia. H. A. U.

COMPOSITAE ADANS.—COMPOSITE FAMILY

*Achillea millefolium* L., yarrow. H. A. U.
*Aster lateriflorus* (L.) Britt., white woodland aster. H. A.
*Aster ontarionis* Wieg., Missouri aster. H. A. U.
*Aster sagittifolius* Wedem., arrow-leaved aster. H. A. U.
*Aster shortii* Lindl., Short's aster. H. A. U.
*Bidens aristosa* (Michx.) Britt., western tickseed-sunflower. Th. A.
*Bidens cernua* L., smaller bur-marigold. Th.
*Cacalia muhlenbergii* (Sch.-Bip.) Fern., indian-plantain. H. U.
*Cirsium vulgare* (Savi) Airy-Shaw, bull thistle. H. A. U.

*Eclipta alba* (L.) Hassk., verba-de-tago. Th.
*Erigeron annuus* (L.) Pers., whitetop. Th. U.
*Erigeron philadelphicus* L., Philadelphia fleabane. H. A. U.
*Eupatorium purpureum* L., joe-pye weed. H. A. U.
*Eupatorium rugosum* Houtt., white snakeroot. H. A. U.
*Heliopsis helianthoides* (L.) Sweet., heliopsis. H. A.
*Lactuca canadensis* L., wild lettuce. H. A. U.
*Lactuca floridana* (L.) Gaertn., Florida lettuce. Th. A. U.
*Prenanthes crepidinea* Michx., rattlesnake-root. H.
*Rudbeckia laciniata* L., goldenglow. H. A. U.
*Rudbeckia triloba* L., brown-eyed susan. H. A. U.
*Solidago latifolia* L., broad-leaved goldenrod. H. U.
*Solidago ulmifolia* Muhl., elm-leaved goldenrod. H. A.
*Taraxacum officinale* Weber, common dandelion. H. A. U.
*Verbesina alternifolia* (L.) Britt., yellow ironweed. H. A.

## Composition of the Dominant Vegetation

Forty species of trees and shrubs are listed in the checklist. Twenty-seven species of trees are recorded for the 9.9-acre strip-transect sample (table 2). Density of stems 3.0 inches and greater d.b.h. is 96 per acre.

Table 2.—Number of Stems in Size Classes and Percentage of Relative Abundance for Trees Measured in the 9.9-acre Strip-Transect Sample.

| Species | Size classes, inches d.b.h. | | | | Number of stems | Percentage of relative abundance |
|---|---|---|---|---|---|---|
| | 3.0-7.9 | 8.0-11.9 | 12.0-23.9 | over 24 | | |
| *Acer saccharum* | 81 | 71 | 92 | 4 | 248 | 26.00 |
| *Ulmus americana* | 72 | 22 | 32 | 7 | 133 | 13.94 |
| *Ulmus rubra* | 60 | 15 | 25 | 11 | 111 | 11.64 |
| *Tilia americana* | 23 | 17 | 15 | 0 | 55 | 5.77 |
| *Celtis occidentalis* | 26 | 16 | 7 | 4 | 53 | 5.55 |
| *Fraxinus americana* | 1 | 9 | 38 | 2 | 50 | 5.24 |
| *Carya ovata* | 14 | 19 | 10 | 0 | 43 | 4.51 |
| *Quercus alba* | 1 | 1 | 10 | 28 | 40 | 4.19 |
| *Carya cordiformis* | 26 | 6 | 6 | 0 | 38 | 3.98 |
| *Ostrya virginiana* | 28 | 0 | 0 | 0 | 28 | 2.94 |
| *Quercus rubra* | 2 | 1 | 10 | 12 | 25 | 2.62 |
| *Fraxinus lanceolata* | 1 | 9 | 12 | 1 | 23 | 2.41 |
| *Fraxinus quadrangulata* | 2 | 9 | 5 | 0 | 16 | 1.68 |
| *Asimina triloba* | 16 | 0 | 0 | 0 | 16 | 1.68 |
| *Crataegus mollis* | 13 | 2 | 0 | 0 | 15 | 1.57 |
| *Juglans nigra* | 0 | 1 | 11 | 0 | 12 | 1.31 |
| *Carpinus caroliniana* | 10 | 0 | 0 | 0 | 10 | 1.05 |
| *Gleditsia triacanthos* | 2 | 1 | 3 | 0 | 6 | 0.63 |
| *Carya tomentosa* | 2 | 2 | 2 | 0 | 6 | 0.63 |
| *Gymnocladus dioica* | 1 | 2 | 1 | 1 | 5 | 0.52 |
| *Platanus occidentalis* | 0 | 0 | 3 | 2 | 5 | 0.52 |
| *Morus rubra* | 4 | 1 | 0 | 0 | 5 | 0.52 |
| *Quercus macrocarpa* | 0 | 0 | 0 | 4 | 4 | 0.42 |
| *Quercus velutina* | 0 | 0 | 3 | 0 | 3 | 0.31 |
| *Acer negundo* | 1 | 0 | 1 | 0 | 2 | 0.21 |
| *Prunus serotina* | 1 | 0 | 0 | 0 | 1 | 0.10 |
| *Quercus muhlenbergii* | 0 | 0 | 0 | 1 | 1 | 0.10 |
| Totals | 387 | 204 | 286 | 77 | 954 | 100.04 |

TABLE 3.—SIZE CLASSES AND DEVELOPMENTAL STAGES AS MODIFIED FROM GUISE (1950).

| Class | d.b.h. in inches | Stages of development |
|---|---|---|
| Sapling | 0.1 to 2.9 | Brushwood |
| Small Pole | 3.0 to 7.9 | Polewood |
| Large Pole | 8.0 to 11.9 | Polewood |
| Standard | 12.0 to 23.9 | Young Timber |
| Veteran | 24.0 and over | Old Timber |

Sugar maples are the most abundant, while the American elms and slippery elms are next in rank, respectively. These three species account for 51.6 percent of the total number, while the remaining 24 species account for 48.4 percent.

When stems are classified according to size classes and developmental stages given in table 3, sugar maples are most numerous in the polewood and young timber stages of development, while only a small number are in the old timber stage. American elms and slippery elms are most numerous in the polewood stage, particularly the small pole class, and they are least in the old timber stage. In view of this evidence, it may be concluded that the Funk Forest Natural Area represents a maple-elm association chiefly composed of sugar maples, American elms, and slippery elms.

The greater relative abundance of veteran oaks in the old timber stage appears to be significant (table 4). The data indicate that this forest is undergoing successional development in which a maple-elm group is becoming dominant and is replacing an older oak group.

## LIFE-FORM SPECTRUM

Raunkiaer's life-form system was used to supplement analysis of the dominant vegetation. The resulting life-form spectrum provides an additional measure of the vegetational physiognomy and evaluation of the component species. These data may serve as a foundation for future periodic investigations of the herbace-

TABLE 4.—PERCENTAGE OF RELATIVE ABUNDANCE FOR STEMS OF THE OAK GROUP AND THE MAPLE-ELM GROUP IN THREE DEVELOPMENTAL STAGES.

*A. Oak group.*

| Stage of development | White oak | Red oak | Bur oak | Black oak | Chinquapin oak | Average percentage |
|---|---|---|---|---|---|---|
| Polewood | 5.0 | 12.0 | 0.0 | 0.0 | 0.0 | 3.4 |
| Young Timber | 25.0 | 40.0 | 0.0 | 100.0 | 0.0 | 33.0 |
| Old Timber | 70.0 | 48.0 | 100.0 | 0.0 | 100.0 | 63.6 |

*B. Maple-elm group.*

| Stage of development | Sugar maple | American elm | Slippery elm | Average percentage |
|---|---|---|---|---|
| Polewood | 61.3 | 70.7 | 67.6 | 66.5 |
| Young Timber | 37.1 | 24.1 | 22.5 | 27.9 |
| Old Timber | 1.6 | 5.2 | 9.9 | 5.6 |

ous as well as of the dominant woody vegetation that characterizes successional development in this maple-elm community.

For pertinent summaries of Raunkiaer's life-form concept, see Adamson (1939) and Cain (1950). The term "life-form" is applied to that part of the vegetative structure of a plant that survives unfavorable climatic seasons as a perennating bud or apical shoot. It is a category describing the plant body apart from reproductive structures, floral parts, or other morphological characteristics upon which phyletic classifications are based. Plants that possess vegetative structures of the same general morphological type are members of a given life-form class, irrespective of their position in the schema of an ordinal system (Cain, 1950).

Raunkiaer (1934) selected, as the basis of his life-form system, a form of vegetative structure which provides the meristematic tissues with optimum protection from critical conditions, as drought or cold. His original classification included five major divisions with thirty subdivisions, all based on differentiation of structures that protect the perennating bud. Life-forms in each of the major divisions progress from those which afford least protection to those which afford the most protection to the meristematic tissues.

For the purpose of this investigation, only those categories are described below that are useful in determining a life-form spectrum for the Funk Forest Natural Area. A classification noted for each species in the checklist is restricted to the members recorded within Division II, Spermatophyta.

*Division I.* Phanerophytes (Ph). Perennating buds are borne on stems that project into the air. These afford least protection to meristematic tissues.

*Division II.* Chamaephytes (Ch). Perennating buds are situated on or within 25 centimeters of the soil surface. Withered foliage, duff, and snowcover afford protection to the meristematic tissues in winter, while foliage and duff afford protection during drought periods.

*Division III.* Hemicryptophytes (H). Perennating buds are situated in the soil surface where they receive additional protection by a thin earth covering.

*Division IV.* Cryptophytes (Cr). Perennating buds are situated at varied levels beneath the soil surface or water, or in soil under water, that are concomitant with the species concerned. They receive greater protection in these media than do surface or aerial buds.

*Division V.* Therophytes (Th). Perennating buds are contained in embryonic form within seeds. This form is considered to give optimum protection of meristematic tissues.

Raunkiaer's "spectrum" for life-forms expresses the distribution in life-form classes of species comprising a flora. It reflects relationships of the flora to the general phytoclimate of large climatic areas (Raunkiaer, 1934). It provides a comparative basis for total regional flora. Since many spectra are based upon total floral populations, it may be important to supplement them with determinations of the relative importance of species in plant communities of undisturbed climax and sub-

climax types (Adamson, 1939). Thus, utilization of these techniques to smaller culturally undisturbed plant communities should be useful in indicating effects of local physical environmental influences, such as edaphic, drainage and micro-climatic factors, upon adaptive vegetative forms of component plant species.

The spectrum for the Funk Forest Natural Area indicates a hemicryptophytic climate (table 5). This is in agreement with the phytoclimate for the humid temperate zone (Cain, 1945). It is third in rank when spectra for certain North American deciduous forests are arranged in decreasing order of hemicryptophytic percentages. It is comparable to two more northern communities in Alberta and Michigan. It is least similar to a Cincinnati upland forest. The difference in the north-to-south distribution of hemicryptophytic life-forms indicates differences in latitudinal and altitudinal phytoclimates which are in turn modified by local environmental influences that characterize various micro-phytoclimates.

## Summary and Conclusions

The Funk Forest Natural Area is a well-preserved 63-acre remnant of a stream-belt type of east-central Illinois deciduous forest. The physical environment is an undulatory moraine covered by upland timber soil

Table 5.—Life-Form Spectra for Eight Temperate North American Deciduous Forest Communities.

| Plant community, location and source of data | Number species | Percentages in life-form classes | | | | |
|---|---|---|---|---|---|---|
| | | Ph | Ch | H | Cr | Th |
| Raunkiaer normal spectrum | 1,000 | 46.0 | 9.0 | 26.0 | 6.0 | 13.0 |
| Poplar association, Alberta, Canada (Moss, 1932) | 170 | 25.8 | 1.8 | 48.2 | 17.1 | 7.0 |
| Aspen association, northern lower Michigan (Gates, 1930) | 310 | 22.9 | 3.9 | 47.1 | 16.1 | 10.3 |
| Maple-elm forest, Funk Forest Natural Area, east-central Illinois | 205 | 23.4 | 2.0 | 44.4 | 20.4 | 9.8 |
| Oak-hickory climax, Piedmont area, North Carolina (Oosting, 1942) | 89 | 59.6 | 0.0 | 36.0 | 4.5 | 0.0 |
| Mixed mesophytic climax, Cincinnati region, Ohio (Withrow, 1932) | 127 | 33.6 | 3.9 | 34.4 | 23.4 | 3.9 |
| Oak woods, Long Island (Cain, 1936) | 92 | 34.8 | 10.9 | 32.6 | 20.6 | 1.1 |
| Cove hardwoods mixed mesophytic, Smoky Mtns., Tenn. (Cain, 1945) | 113 | 36.3 | 4.4 | 30.1 | 25.8 | 3.4 |
| Upland forest, Cincinnati region (Withrow, 1932) | 94 | 49.8 | 4.2 | 23.4 | 15.9 | 6.4 |

and bottomland soil, drained and dissected by two streams. During the period of this investigation, 1950 and 1951, the temperatures were cooler than normal, precipitation was above normal, and the growing season was longer than normal.

Vascular plants included 213 species in 148 genera and 69 families. About 57 percent of the plant species are in common with all four University of Illinois woodland preserves, whereas only 12 percent were recorded for only the Funk Forest Natural Area. The plant community represents a maple-elm association, chiefly composed of trees in polewood and standard stages of development. Application of Raunkiaer's life-form system indicates a hemicryptophytic phytoclimate comparable to two more northern deciduous forest communities.

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# RECENT ADVANCES IN THE FIELD OF FOREST GENETICS

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Forest genetics is beginning to come of age, having but recently passed through an awkward and confused stage of early growth. It has been slow to follow the lead of plant breeding in agriculture and horticulture. The reasons lie not so much in scientific backwardness as in the economic and biological conditions that surround the growing of timber products.

Much of our timber in the past has been "mined" rather than consciously grown. It seemed to be present in almost unlimited amounts. The price of stumpage was relatively low and there was little economic incentive to practice the scientific culture of forests. In addition, the great length of a tree generation and the inadequate knowledge of vegetative propagation of forest trees were further barriers to rapid advances in forest genetics. Because of these economic and biological factors, forestry training in the past has been lacking or weak in the science of heredity, and this science has not always been adequately applied in the practice of forestry.

But all this has now been changed. First of all, we are faced with the necessity of growing our own timber as a crop. The virgin forests are nearly gone in the United States and the supply of timber from foreign sources is limited. If we must grow our own trees, why not grow good ones? Second, the impact of highly successful breeding work with other plants and the almost spectacular results from some early experiments with trees has shown the need for research in forest genetics and for the application of the results to silviculture.

This paper summarizes the background for recent advances in forest genetics, states the general goals of a forest genetics program, shows some of the progress toward those goals, and outlines future prospects.

## Background

Most of the early observation and research in forest genetics was made in the field of provenance, i.e., geographic or climatic races (ecotypes) within a species. The occurrence of climatic races was impressed upon foresters by the usually definite and sometimes spectacular results of planting young trees or seed far from the native seed source. High altitude strains of a species when planted in the lowlands retained their alpine characteristics. Progeny of seed from a lowland source suffered severe freeze damage when planted at higher altitudes. Wide distances in latitude, and even in longitude, between seed source and planting site often caused bad results. The evidence for the existence of geographic or climatic strains

within species is now rather conclusive (3, 9). Provenance studies have not only had real practical value in themselves but have stimulated advancements in other, more intensive phases of genetics.

Past exploitation of forests through retrogressive selection and bad choice of seed have reduced the proportion of good genotypes in the world's forest population. This fact has been recognized only recently. In Sweden heavy and prolonged selective fellings, which took only the best trees, has resulted in some deterioration of the forests, and collection of seed from inferior parent trees has resulted in plantations of poor quality (9). The same thing has happened in this country (6, 13, 15), but only recently have we realized the true genetic significance of these events. It has been strongly emphasized that valuable genetic combinations, once lost in a population, cannot be recovered by breeding in that population (9).

Research foresters, aided by plant geneticists, are now well on the way toward providing facts and procedures through which superior trees and forests can be developed and grown. In this country one of the leaders in the field is the Institute of Forest Genetics of the U. S. Forest Service (26).

## Goals of a Forest Genetics Program

Probably all the aims of a forest genetics program can be grouped under three general objectives (2, 4, 17, 23, 28):

(1) Delineate geographic races and determine the limits of range around the planting site within which the seed of a given species should be collected. Many provenance studies of this nature have been concluded or are nearing completion. The results of these studies will aid greatly in the realization of the other two main objectives.

(2) The discovery, perpetuation, and dissemination of the best remaining genotypes still present in natural stands or plantations.

(3) The further improvement of the better genotypes by controlled breeding and hybridization.

The attributes of forest trees may be good or bad depending upon: (1) the suitability of geographic seed source, (2) inheritance of specific characteristics in individual trees, or (3) the effect of environment (important as environment is to tree growth we cannot consider it here). Inherited tree characteristics are manifest through tree vigor, tree quality, and resistance to damaging factors. Either disharmonious geographic seed source or certain inferior genes may be responsible for low vigor, poor quality, or low resistance. For example, a given tree genotype, when grown within its own climatic and edaphic range, might produce trees of high vigor, good quality, and high resistance. If grown in a disharmonious climate or soil, this same genotype usually would produce trees with undesirable characteristics of either vigor, quality, resistance, or perhaps all three. Conversely, trees located within a harmonious climatic range inherit specific characteristics which may result in low or high vigor, quality, or resistance. Fortunately, disharmonious geographic range can be easily avoided. Foresters are now

generally agreed that trees should not be planted far from their native seed source until it is demonstrated that a particular strain will be successful.

The goals of a forest genetics program are concerned with determining how and to what degree the various tree characteristics are inherited, how this inheritance is influenced by environment, and how trees with superior traits can be produced. The following characteristics are believed to be inherited to a greater or lesser extent and worthy of intensive research (6, 9) :

*Vigor*

(1) Growth rate and ultimate size. This includes both height and volume in a given environment on both an individual tree and a forest stand basis.

(2) Reproductive vigor. Trees of high growth potential may not be highly fruitful.

(3) Yield of special products such as oleoresin and maple sugar.

*Quality*

(1) Stem characteristics: (a) straightness; (b) taper and shape; (c) natural pruning; (d) apical dominance (strong central stem with an absence of forking); (e) epicormic sprouting (sprouting along the stem greatly lowers the lumber quality).

(2) Crown characteristics: (a) shape—relatively long, slim crowns are usually preferable because they allow more trees per acre without crowding; (b) branch size—relatively small branches are usually preferable because they produce smaller knots and a larger proportion of the total volume of the tree is composed of stem wood.

(3) Physical properties of wood: (a) straightness of grain; (b) special properties such as "bird's-eye" and curly grain; (c) wood density.

(4) Chemical properties of wood such as proportion of cellulose and tannin.

*Resistance*

(1) Hardiness to climatic extremes.

(2) Resistance to disease.

(3) Resistance to insect attacks.

## Progress Toward the Goals

The greatest progress in forest genetics has been made in the field of provenance or geographic strains. The evidence is now conclusive that geographic strains do exist and that local seed sources are usually best for planting in a given place. The literature on this subject is voluminous and only a few examples are given here. The geographic source of loblolly pine (*Pinus taeda* L.) seed directly affected the growth, yield, and disease resistance of plantations (27). The differences among sources were even greater than those caused by large changes in site quality. Altitudinal races in ponderosa pine (*Pinus ponderosa* Laws.) have been demonstrated (18). Progeny of red pine (*Pinus resinosa* Ait.) differed in survival and early growth depending upon the geographic source of the parent trees (8, 21), and similar results were obtained with jack pine (*Pinus banksiana* Lamb.) (22).

Progeny tests in Europe with 20 sources of spruce and pine planted in several localities showed that the local sources were best in all cases (7). Other extensive tests in Europe showed that plant breeding material should be collected from the same

region where it is to be grown (20). Most American workers in forest genetics now generally agree that local native seed sources should usually be used for reforestation purposes. Exceptions to this rule do exist. Sometimes even exotic species thrive in a new environment. If the new climate is not too different from the parent climate, some imported strains may be superior to trees from local seed sources. The discovery and propagation of these really superior genotypes is one problem of genetics research.

A slightly different provenance problem is encountered in southern Illinois. This region has no native pine and, so far, introduced loblolly and shortleaf pine (*Pinus echinata* Mill.) have proved to be the best species for reforesting the worn-out and eroded old fields of the region. Until a few years ago, little attention was paid to the source of the seed to be used in southern Illinois.

Starting in 1949, the Carbondale Research Center established a series of replicated field trials including seven sources each of loblolly and shortleaf pine. During the second winter, loblolly progeny from Mississippi, South Carolina, and southeastern North Carolina suffered severe freeze damage (16). Trees grown from seed collected in Arkansas suffered only moderate damage, while trees from Maryland, Virginia, and Tennessee seeds were free of injury (fig. 1). At the end of the third year, survival, height growth, and form of the northern-source

FIG. 1.—Loblolly pines grown in southern Illinois from seed from different sources show marked differences in appearance three years after planting. The source of the trees to the left of the white 2½-foot plot stake is Worcester County, Maryland. The source of those to the right is Pender County, North Carolina. The Maryland trees are taller, have denser and darker foliage, and show better form and survival.

progeny were significantly better than for the southern-source trees. Progeny of hybrid crosses between loblolly and shortleaf pine planted in other southern Illinois experimental plots were undamaged. At the State Tree Nursery near Jonesboro, Illinois, whole beds of loblolly pine seedlings from eastern South Carolina seed were killed by the cold, while adjacent beds from Maryland seed remained virtually undamaged.

Other differences among the various sources on the experimental plots will undoubtedly develop as the trees become older. In this particular case our objective is to find or develop a strain of southern pine well suited to the climate and soils in southern Illinois.

Evidence that individual trees inherit traits of vigor and quality independent of environment has gradually accumulated. The methods of study used have been chiefly progeny tests, controlled breeding, and hybridization. In Australia (19) open-pollinated seed from exceptionally good (plus) loblolly and slash pine (*Pinus caribaea* Morelet) trees produced twice as many superior progeny as the average seed. By inbreeding the best trees, 3.5 times more superior progeny were produced than from average trees. The 5-year results of a one-parent progeny test (14) with loblolly pine in South Carolina showed highly significant differences in height growth and survival between the progenies. Similar results have been obtained with Scots pine (*Pinus sylvestris* L.) (10) and black locust (*Robinia pseudoacacia* L.) (5). Progeny tests with Monterey pine (*Pinus radiata*) in South Africa (24) showed that vigor, branch size, length of internode, stem straightness, and crown shape were inherited independently of environment. Latex production from rubber trees has been trebled by seed selection (11). The capacity of longleaf pine (*Pinus palustris* Mill.) for the production of oleoresin is an inherited variant (12). Forestry practice in Sweden and some other European countries is based directly upon the use of "plus" trees and "elite" stands for seed production and breeding purposes.

It will not surprise plant scientists to hear that trees inherit resistance to diseases and insects. The location and breeding of such resistant strains, however, has been a slow process and lags far behind work on food crops. Disease resistance of trees has been shown in a few cases. About half of the progeny of open-pollinated mimosa (*Albizzia sp.*) trees resistant to the mimosa wilt were themselves r e s i s t a n t, whereas almost none of the progeny from average seed were resistant (25). Rooted cuttings from resistant trees showed high resistance. Slash pine trees resistant to the pine rust canker have been observed in the South (6). The Division of Forest Pathology, U. S. Department of Agriculture, together with some private nurseries, has for years been breeding and testing blight-resistant strains and hybrids of chestnut (*Castanea sp.*). This work has been based partly on Asiatic breeding stock. Several resistant strains, which promise to have desirable nut and timber producing traits, are now available. Some of these are now being tested on our Kaskaskia Experimental Forest. Intensive work in the interior region of the United States is now being conducted on the

location and breeding of western white pine (*Pinus monticola* Dougl.) trees resistant to the white pine blister rust (1). The work has already uncovered several apparently resistant strains, and several phenotypes of exceptionally high quality have been found.

## A Look Ahead

Someday in the future, American forestry will have an adequate scientific program which will include the intensive application of forest genetics to silviculture. It will include a seed procurement policy based on seed orchards of trees or elite stands with proved superiority. Trees will be grown only in climatic or edaphic environments to which they are adapted and these geographic zones will be known and delineated. Superior strains and hybrids will be used for all reforestation purposes. Through careful selection, natural stands will consist largely of high quality, vigorous, and pest-resistant trees, and the best or elite trees will be reserved for seed. It is also not inconceivable that trees will be bred for particular purposes, for example, high-cellulose trees for making paper or rayon, high wood density and strength properties for certain structural uses, and high yielders of oleoresin for production of naval stores. Forest genetics research and its application to forestry practice has just begun.

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# CHEMISTRY

## SURVIVAL FOLLOWING TREATMENT WITH SULFONES IN EXPERIMENTAL TUBERCULOSIS IN GUINEA PIGS

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From the time that Robert Koch isolated and successfully cultured *Mycobacterium tuberculosis hominis,* the bacillus causing tuberculosis, the world has waited hopefully for an effective means for combating this disease. The chief hope seemed, from the beginning, to lie in bacteriological and vaccine approaches, and since that time there has been constant activity and much progress in these directions. Meanwhile, advances were made in the use of X-rays, testing for early diagnosis, and subsequent sanitarium care where indicated.

Extensive studies were made in the use of drugs and antimicrobial agents in experimental and clinical tuberculosis. The encouraging results led to their use as adjuncts to the older and proved methods of treatment. And now the antimicrobial agents, among them, para-amino salicylic acid, streptomycin, dihydrostreptomycin, and isonicotinic acid hydrazid have become of prime importance and have opened up new potentialities in this field. It is hoped that these advances are only the forerunners of progress to come in the constant search for new and effective agents and methods for the treatment and prevention of this disease.

In order to select new substances more expeditiously, they are usually screened in-vitro so as to establish a table of relative tuberculostatic values. The use of these values presupposes: (1) that the compounds are sufficiently soluble in the culturing media to give an effective concentration, and (2) that some of the compounds which might be effective in animal tests may have been ruled out prematurely. But since it is impractical to establish in-vivo ratings on every compound made available for this purpose, a method is needed even though it has limitations. On this basis it seemed logical to select compounds from a table of correlations between in-vivo and in-vitro ratings. Promin (Sodium P,P′-Diaminodiphenylsulfone-N,N′Didextrosesulfonate) and Sulfone 1048 (Disodium salt of N,N′Bis-(B-carboxy-B-acetamido-ethylthiamethyl)-4,4′-diaminodiphenylsulfone) appeared to be the most promising from the results of these studies. They also demonstrated further promise in some exploratory studies against experimental tuberculosis, previously reported (1), and were, therefore, selected for these studies.

### Method

Previous work demonstrated that under optimum conditions Sulphone 1048 retarded or inhibited the tuberculous process to such a degree that

there were no macroscopic post mortem findings. The duration of these experiments was 45 days. It would have been of interest had we been able to prolong these experiments indefinitely to determine if positive findings would develop. Consequently in designing the experiments for this investigation the purpose was not so much to determine how effective these drugs were but rather to determine what the prolonged effect would be following a comparatively short period of treatment.

*Animals and controls.* — Thirty young female guinea pigs were adjusted to the routine of the animal room for nine weeks. At the end of this time their weights ranged from 610 to 730 grams. The left groin of each pig was inoculated with 0.0005 mg. of H37 RV tubercle bacilli which was cultivated for one month on Saenz media. The infecting emulsion was prepared by mechanically suspending a weighed quantity of the tubercle bacilli in a heavy-walled glass tube equipped with a pestle ground to fit (2). The bacilli were first ground in a mechanical grinder and gradually brought to the required concentration by diluting the suspension with physiological salt solution.

*Drug therapy.* — Treatment was started two days after infection and continued daily for 58 days. The drug was administered by mixing it with chopped green vegetables in sufficient quantity so that the Promin treated group received 400 mg. per pig per day, and the Sulfone 1048 treated group received 300 mg. per pig per day. The addition of 40 percent sucrose syrup made this mixture more acceptable to the guinea pigs. For purposes of control each animal in the control group received the same quantity of chopped vegetables and sucrose syrup daily. In previous work we and other workers have consistently obtained uniform results with this technique. After 60 days the animals were given only routine care, and autopsy findings were recorded after death.

*Complications.*—During the course of this experiment three animals died of pneumonia. There was the possible contributing factor of a protracted heat spell, for it was during such a period, 64 to 67 days after the experiment started, that these animals died. Three animals, one from each group, were sacrificed one month after the experiment started to observe the progress of the disease. These findings are discussed below.

## Results

Ordinarily, comparative survival times are calculated from the date of infection of the experimental animals. On this basis the average survival time of the treated animals was more than three times as long as that of the untreated control animals; 68 days was the average survival time of the controls as compared with 211 days for the Promin treated group and 227 days for those treated with Sulfone 1048. These comparisons significantly indicate the effectiveness of these drugs against experimental tuberculosis in guinea pigs. They show that Sulfone 1048 is somewhat more effective than Promin, a trend consistently obtained in our in-vivo and in-vitro experiments.

For this discussion, however, it is more instructive to compare the survival times for those periods during which no treatment was given. Therefore, inasmuch as treatment was stopped 60 days after the infecting inoculation was administered, 60 days are subtracted from the above survival period of the treated groups. This leaves 151 days for the Promin treated group and 167 days for the Sulfone 1048 group, or more than twice as long in each series as the average life span of the control group.

Importance is attached to this observation because under comparable circumstances it should be anticipated that animals starting with a considerable amount of tuberculosis would die sooner than a freshly infected group of animals; instead, the reverse of this was true. That there was a formidable amount of tuberculosis at around 60 days is established by evidence that was obtained from the post-mortem findings of a limited number of animals sacrificed during this period, and from the findings in those animals dying meanwhile of other causes. The post-mortem ratings at 32 days for Promin treated animals was 68; for the Sulfone treated animals it was 16; and for the control animals at 26 days it was 68. At 64 and 67 days the treated animals showed ratings of 68 and 90, while the rating in the control animals was 100 at 37 days and beyond. Also, it may be established, on the basis of presumptive evidence from comparable experiments, that while the animals were under treatment the disease progressively increased with time. This evidence is derived from a series of 113 guinea pigs similarly treated with the above and similar sulfones. Periodically groups of these animals were sacrificed within a period of 26 to 100 days. A composite summary of the post-mortem ratings is shown in table 1.

Table 1 shows that the treated animals developed tuberculosis at a slower rate than the control animals did. However, in less than 4 months the amount of involvement was equal to or greater than the lethal amounts found in the control groups. After 4 months, although this is not indicated in the table, the disease continued to spread to such an extent that post-mortem ratings no longer served as a measure of the extent of the disease. Here there is an appar-

TABLE 1.—POST-MORTEM RATINGS

| Treated Groups | | Untreated Groups | |
|---|---|---|---|
| Duration in days | Post-mortem ratings* | Duration in days | Post-mortem ratings* |
| 30 | 0-10% | 26 | 48% |
| 45-66 | 42-57% | 45 | 87% |
| 88-100 | 72-100% | 59 | 88%-100% |
| 116 days and beyond | 100% | 64 days and beyond | 100% |

* In order to estimate the post-mortem rating or gross involvement a sum of 100 was set for maximum involvement, and the individual organs were assigned the following numbers to indicate the maximum gross involvement in that organ:

| | |
|---|---|
| Lymph nodes | 3 |
| Spleen | 24 |
| Liver | 28 |
| Lungs | 40 |

This arbitrary choice is based on the hypothesis that the organs which are most readily involved should be given lower values. Also, since each number is divisible by 4, the common procedure of designating the amount of involvement of each organ by +, ++, +++, ++++ is readily transferred into this system of evaluation.

ent paradox in that more tuberculosis is found in animals receiving beneficial treatment than in untreated groups. This could only come about because the animals developing the disease under the protection of chemotherapy survived for a longer time, thus permitting fuller development of the lesions. The animals in this present series living longer than 4 months lived from 149 to 390 days, and the longer the survival period the more massive the involvement appeared to be.

Obviously the lethal nature of the tuberculosis found here was greatly modified and moderated because of the administration of these drugs. This is all the more significant because there was no localizing of the lesions nor was there any chemical sterilization or signs of regressions. Thus the animal body tolerated large quantities of active tuberculosis over a long period of time.

The suggestion presents itself then that an immunity has been produced, despite the progressive tuberculous process. This may correspond to some clinical observations made in the earlier use of isonicotinic acid hydrazid, used then primarily in cases which did not respond to para-amino salicylic acid or streptomycin therapy. It was reported in some instances that patients under this treatment had a feeling of well being and showed improvement without the corresponding roentenological improvements being found. Also, in chronic cases of tuberculosis there may be extensive involvement, which in other individuals would be sufficient to cause death. Here we have a difference in the response to the organism, probably due to immunological differences.

This leads to the provoking question of how antimicrobial agents may affect the course of disease. In clinical tuberculosis the organisms are present when therapy is begun. Some immunity may have been established by this time, owing to growth of the tubercle bacilli in the host, yet the immunity is insufficient to enable the host to overwhelm the disease without assistance. The question then arises whether the antimicrobial agent produces an added immunization or similar effect, causing further improvement.

That this might be so may be inferred from the preceeding experiments, in which survival time increased for the most part after treatment was stopped. It might also be inferred from some previous studies on the combined action of diamino diphenyl sulfone and immunization (vaccination). In these studies it was determined, among other things, that the combined action of vaccination and the sulfone was more effective than vaccination alone.

## Summary and Conclusions

(1) Sulfone 1048 and Promin were tested against experimental tuberculosis. Both were effective and increased survival time more than three times as compared to the controls.

(2) Sulfone 1048 was more effective than Promin, which corroborates the in-vitro findings.

(3) Although the drugs were administered for only 58 days, the effectiveness remained after treatment stopped, and the animals survived without drugs twice as long as the control animals. Probably some immunological response was stimulated by the action of these drugs.

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# MICROSCOPY AND COLOR PHOTOMICROGRAPHY IN THE STUDY OF FEEDSTUFF QUALITY

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During the past several years there has been a definite trend in the feed industry toward the use of microscopic examination in quality control of feedstuffs. A number of the State Feed Control laboratories have added microscopic examination to their usual chemical determinations of protein, fat, fiber, etc.; indeed at least one submits a color photomicrograph of the feed to the manufacturer to point out contaminants and low quality constituents. Further evidence for the interest in this field was the formation on March 15, 1953, of the Association of Feed Microscopists to formulate and standardize procedures and otherwise promote the work of feed control officials.

Probably the main feature of microscopic examination is that, whereas the conventional chemical methods of analysis only reveal the composition in a general way, i.e., protein, fat, fiber, ash, etc., the expert microscopist can identify the various constituents and tell whether they are desirable or undesirable.

In our laboratory attention has been directed toward quality improvement of feedstuffs of the animal and vegetable protein type. This company specializes in the production of protein-vitamin-mineral concentrates which, when fed along with grain and roughage, provide feeds that are as complete as the modern science of nutrition permits.

One of the best examples of the application of the microscope in this field is meat scrap, an important source of animal protein in many mixed feeds. This feedstuff is obtained either as a by-product in the packing industry or as one of the main products, along with the fat and hides, in the rendering industry. Meat scrap is usually purchased on the basis of protein content, which is determined by chemical analysis. However, the protein percentage is a measure of total protein only and leaves unanswered the important questions of digestibility and quality of protein.

The characteristics of good and poor quality meat scrap are easily distinguished under the microscope, as shown in the two upper photomicrographs in figure 1. The picture on the left shows a good quality product containing very little undesirable material. The rough-textured pieces (brown in color) are well-cooked meat; the white chunky ones are bone, which is not regarded as a contaminant because it furnishes calcium and phosphorus. The photo on the right shows a poor quality product containing hoof, hair, vegetable fiber, and overheated or scorched meat.

The effect of feeding these meat scraps is illustrated by samples A and B in figure 1, in which we see the feces from rats which have been fed each of these products. Sample

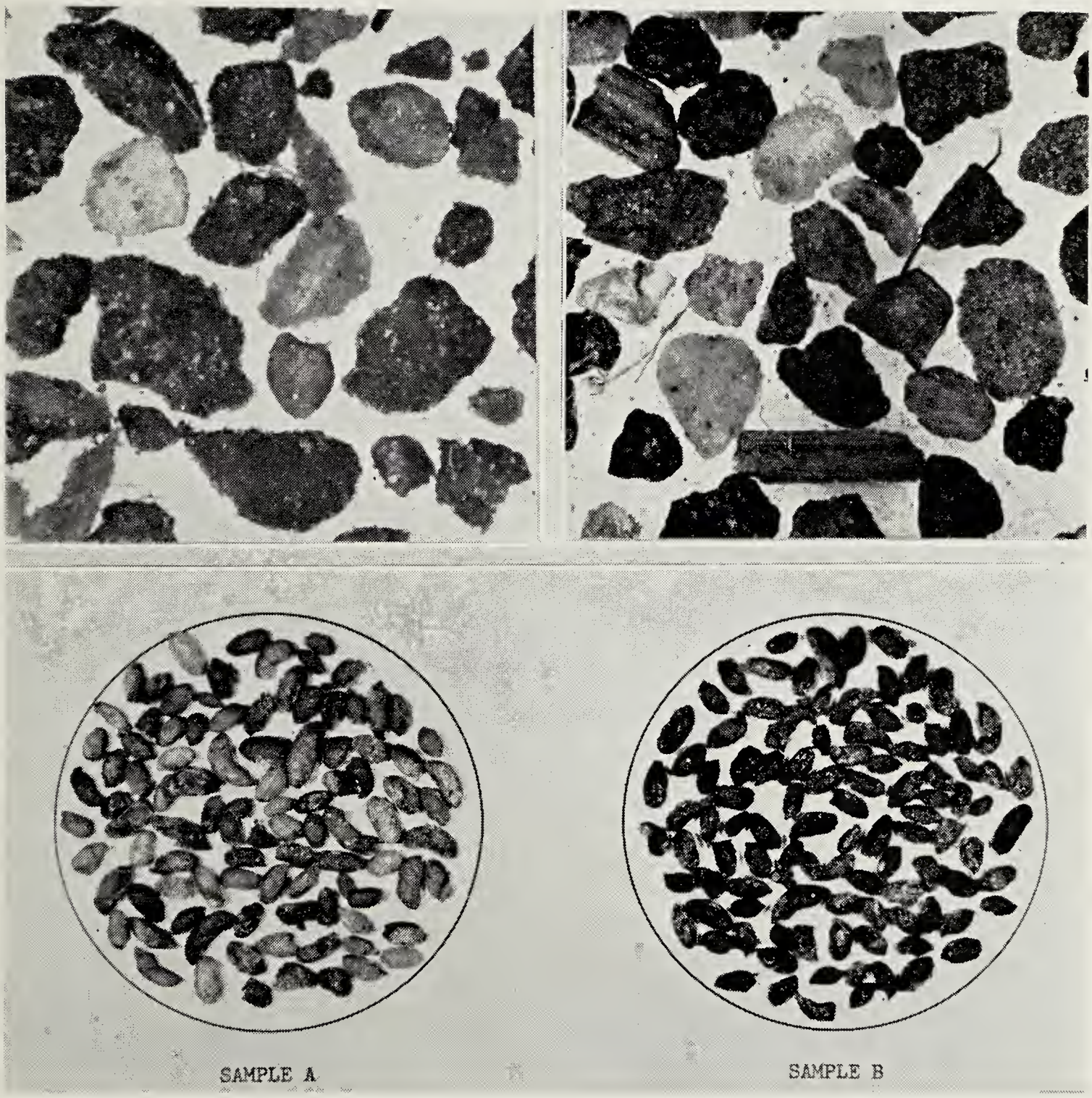


FIG 1.—*Upper left*: Good quality meat scrap consisting of well-cooked meat and bone. *Upper right*: Poor quality meat scrap with scorched pieces and vegetable fibre in addition to good meat and bone. Magnifications 7.5x. *Lower photos* (½ actual size): Comparison of feces from rats fed good quality meat scrap showing normal color (*left*), with feces from rats fed poor quality meat scrap showing black color from overheated meat (*right*).

A shows feces from rats fed the good quality material, and sample B shows those from rats receiving the poor quality product containing overcooked meat and other indigestible ingredients which passed unchanged through the animal, imparting the dark color to the feces. Data from this test and others, when presented to the meat processors, have resulted in the production of meat scraps of greatly improved nutritional value.

Another practical feature of microscopic inspection is its speed. Whereas a chemical analysis will take at least several hours, the evaluation of a sample under the microscope is usually completed in a few minutes. The foregoing discussion of possibilities of this type of quality

control is not meant to imply that the microscope acts as a substitute for chemical analysis; on the contrary, it acts as a supplement and in certain instances shows the necessity for some additional chemical analyses while indicating that others might not be needed.

Proper organization of the inspection program has contributed to its success. When the program was initiated, the variations and undesirable constituents of each raw material were studied to provide a basis for sample evaluation. A check list was then compiled for each feedstuff to insure against failure of the observer to cover all the necessary points. Meat scrap, for example, is evaluated for hair, fuzz, overheated material, vegetable fiber, glass, and hoof. Vegetable proteins are inspected for hull, foreign hull, fiber, and weed seeds. All data are entered on filing cards which cover the items observed microscopically and, in addition, physical properties such as color, odor, and fineness which come to the attention of the microscopist. A simple system for expressing roughly the quantity of each contaminant present is used in recording the data.

In our laboratory every incoming feedstuff is microscopically inspected immediately upon arrival; in fact, sampling of the cars takes place in the railroad yard so that the protein analysis and microscopic inspection are finished before the cars reach our factory. Protein content of the raw materials and any abnormalities revealed by the microscope are reported to the Purchasing Department daily.

Photomicrography, in both black-and-white and color, has become an important tool in our quality control program. Photomicrographs of the various feedstuffs or fractions isolated from them have been very useful to our Purchasing Department when pointing out to a supplier the presence of undesirable constituents which are to be minimized or eliminated. These photographic records have resulted in greatly improved raw material quality in a number of instances.

The undesirable parts of the feedstuffs are separated chemically and then examined under the microscope. In our laboratory the crude fiber from most of the common vegetable proteins has been separated and photographed, giving a better understanding of the nature of this part of the feedstuff.

In addition to detecting impurities in the individual feedstuffs, the microscope can be used effectively in identifying and estimating the various constituents in feed mixtures. Because of the fundamental difference in structure between the various raw materials, each has its own distinctive properties which furnish clues to its identity. In the following discussion the more prominent characteristics of several feedstuffs are briefly described (see Fig. 2).

During the past decade soybean oil meal has become the most widely used vegetable protein. Hulls, weed seeds, and overheating or underheating are clearly visible through the microscope. In the photomicrographs the thin, curled, faintly pitted pieces are hulls. Weed seeds, a common contaminant in vegetable protein and grain by-products, sometimes occur in large numbers. These are easily detected microscopically and may be determined quantitatively by

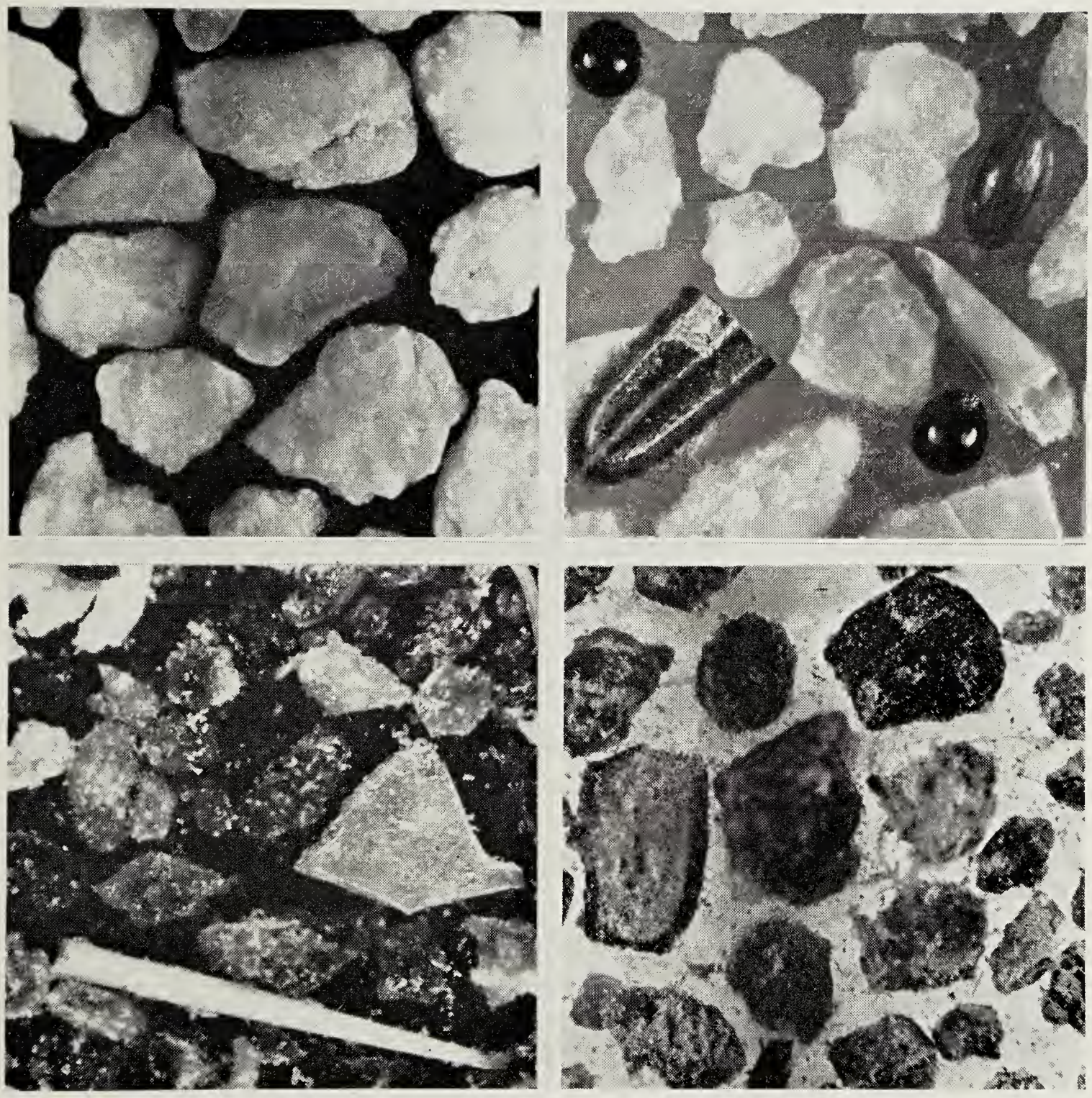

FIG. 2.—*Upper left*: Good quality soybean meal containing no foreign material. *Upper right*: Poor quality soybean meal with hull and weed seeds. *Lower left*: Fish meal, showing characteristic bone and scale. *Lower right*: Cottonseed meal with characteristic black rough-surfaced hull. Magnifications 7.5x.

counting the number of seeds in a weighed sample. Color of soybean oil meal ranges from lemon yellow when undercooked to dark brown when overheated. The two upper photos in figure 2 show the comparison between good quality soybean meal and poor quality meal containing excessive quantities of hull and weed seed.

By far the most important marine source of animal protein is fish meal. In figure 2, lower left, the dark rough-textured pieces (brown in color) are the cooked flesh of the fish and appear similar to meat scrap, but the slender and sometimes pointed white bones and the flat transparent scales differentiate fish meal from other feedstuffs.

Another important vegetable protein, especially in the feeding of cat-

tle and sheep, is cottonseed meal, shown in figure 2, lower right. This product is predominantly yellow in color with rough-surfaced dark-brown hulls which furnish the chief means for its identification.

In general, most of the raw materials received are found to be free from serious contamination. This is especially true of vegetable proteins. It is recognized that products such as soybean oil meal and cottonseed meal normally contain some hull. However, this is not undesirable except insofar as it reduces the protein content and increases the percentage of crude fiber. As previously mentioned, certain samples of meat scrap have been found which contain considerable quantities of hoof, hair, vegetable fiber (from the stomach or intestinal tract), and scorched meat. Impurities such as hoof, hair, and scorched meat are undesirable because of their high percentage of indigestible protein. Microscopy detects these contaminants which are not differentiated from good quality protein by the chemical Kjeldahl method.

The photographic equipment used in this work is simple and may be on hand in many laboratories or purchased at a reasonable figure. We use a Zeiss low-power stereoscopic microscope equipped with objectives and eyepieces permitting from 4 to 32 diameters magnification. Photomicrographs are taken with a Speed Graphic Camera, which is rigidly supported above one eyepiece of the microscope and accurately aligned so that the plane of the camera film is perpendicular to the optical axis of the microscope. Focusing is done on the camera ground glass. The sample is illuminated by two No. 1 Photoflood bulbs in metal reflectors placed at angles of approximately 45° above the stage and about 8 inches from the specimen. Cut film is used in black-and-white work, while Kodachrome roll film in a sliding back is used for color. Exposure must be determined by experiment. However, when once established it remains practically constant unless the lighting is radically changed.

As might be expected, color photography has been much more effective than black and white although it is somewhat limited from the standpoint of speed of processing and expense of making paper prints. In our laboratory it has been found quite feasible to project the photomicrographs as Kodachrome transparencies in a viewer or projector. The newer methods for paper prints in color which can be processed by the photographer might be practical in cases where much work of this type is involved.

The foregoing discussion has been presented to point out a few of the ways in which the microscope and camera are being used in product improvement. It is possible for the trained observer to learn much about a raw material in a minimum of time by microscopic inspection. Microscopic examination does not replace the time-honored feed analyses of protein, fat, fiber, ash, etc.; but used in combination with these, microscopy becomes a powerful tool in the quality control of commercial feedstuffs.

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# FLAVOR AND VITAMIN STABILITY IN FLUID MILK

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The factors involved in the flavor and vitamin stability of fluid milk have not been established with any marked degree of agreement despite the numerous studies published to correlate these variables. The purpose of this report is to present some of the particularly controversial issues as well as a possible reconciliation developed from studies made in this laboratory.

## Vitamin Deterioration

A partial explanation of the relationship of riboflavin, ascorbic acid, light, and oxygen in milk was presented by Hand and coworkers (11) in 1938. They demonstrated that when all ascorbic acid and riboflavin were removed from milk and then ascorbic acid replaced, very little ascorbic acid was lost until riboflavin was added. Similarly, when the riboflavin was removed from milk by adsorption or destruction, the ascorbic acid became more stable. When the oxygen was removed from milk, the ascorbic acid loss was reduced, but not to the same extent as when the riboflavin was eliminated. Thus, the authors concluded, "Lactoflavin is the sole agent in milk responsible for the sensitivity of ascorbic acid to light." These findings were further verified by later studies (12).

The photo-oxidation of riboflavin in milk was also described by Williams and Cheldelin (24), who reported that 64 percent was lost when milk was boiled in a lighted room for 45 minutes, but only 5 percent was destroyed when identical samples were boiled in the dark. The fact that the loss of riboflavin may be as high as 85 percent on exposure of milk to sunlight in a period of 2 hours has also been demonstrated, together with the practically total loss of ascorbic acid within the first 30 minutes of the experiment (15). The same workers (15) showed that two identical samples of milk would lose riboflavin in direct proportion to the intensity of the light falling on each sample. In this connection, Stamberg and Theophilus (22) observed that the destruction of riboflavin by light was greater in raw milk than in pasteurized. The least destruction was incurred by homogenized-pasteurized milk. Although not expressed by the authors, here is excellent evidence of the possible role played by enzymes in milk deterioration, although phosphatase itself in raw milk merely accelerates the breakdown which ultimately occurs in processed milk.

## Flavor Deterioration

The oxidized flavor which becomes evident in milk after exposure to light, air and prolonged storage conditions has been variously reported (3, 4, 7, 8, 10). However, the exact origin and nature of this objectionable quality has not been described, nor has the relationship between the development of the oxidized flavor and the concentration of both ribo-

flavin and ascorbic acid in milk been clearly explained. Krukovsky and Guthrie (18, 19) have claimed that ascorbic acid definitely accelerated the development of oxidized flavor in milk and that the maximum acceleration occurred when the ascorbic acid was a mixture of the reduced and dehydro forms. Rapid oxidation of ascorbic acid beyond the dehydro stage presumably eliminated its prooxidant effect.

The 1938 work of Hand, Guthrie, and Sharp (11) referred to studies carried out by Sharp in 1936 in which it was found that addition of 0.005—0.01 percent ascorbic acid to milk delayed the development of oxidized flavor, thus establishing an apparent contradiction to the 1945 and 1946 work of Krukovsky and Guthrie (18, 19). Chilson and coworkers (2) have found that the addition of 1.5 grams ascorbic acid (0.003 percent) to 100 pounds of milk prevented the formation of oxidized flavor even after the seventh day of dark refrigerated storage, whereas the control samples developed an oxidized flavor after 2 days of such storage. Milk fortified with ascorbic acid, however, rapidly lost it on exposure to sunlight or on treatment with hydrogen peroxide. Nevertheless, the authors found that no oxidized flavor occurred in the milk even after a 5-day storage period. This does not appear to detract from the work of Krukovsky and Guthrie (18, 19), who have emphasized the development and control of oxidized flavor under conditions similar to those described in the Chilson paper. However, neither group attempted to correlate the riboflavin content itself with oxidized flavor.

Recently, Holmes (14) made a study of mare's milk in order to learn why ascorbic acid disappeared from cow's milk ten times faster than from mare's milk when both were stored under the same conditions. While Holmes did not mention the oxidized-flavor relationship, his paper has significance in this regard, as will be indicated later. The rapid destruction of ascorbic acid was first assumed to be due to the fact that cow's milk contained much more riboflavin than mare's milk; Holmes decided to study the effect of adding riboflavin to samples of mare's milk in order to observe the reaction upon the reduced ascorbic acid content. The sample enriched with 2 mg. of riboflavin per liter lost 3.8 percent reduced ascorbic acid daily, and the sample treated with 4 mg. per liter lost 4.1 percent ascorbic acid; but at the end of a 5-day storage period in the dark at 10°C., both samples retained about 85 percent of their original reduced ascorbic acid. These data were interpreted as indicating that riboflavin was not the principal factor in causing the rapid disappearance of ascorbic acid from milk stored in the dark at 10°C. The interesting graph presented by Holmes illustrating these data will be discussed later. In the interim, the conclusion that riboflavin was not the principal cause of the ascorbic acid loss in mare's milk adds to the complexity of the problem. This study does not appear to be a reaction activated by prolonged light exposures, although the description of the experimental conditions does allow for considerable light radiation and aeration during the early stages of the investigation.

## Mechanism for Vitamin and Flavor Deterioration

In 1945-46 (6) during an investigation of the conditions (light, temperature, storage period) affecting the vitamin content and general composition of raw and processed cow's milk, the writer observed that the concentrations of components determined to a large extent the storage stability of the milk. For example, the various batches of pasteurized milk contained the following ranges, per 100 ml. of sample, of what were considered to be the most critical components: 0.11–0.19 mg. of riboflavin, 1.0–1.9 mg. of ascorbic acid, 0.24–0.28 mg. of iron, and 0.020–0.024 mg. of copper. Thus, there were sufficient amounts of iron to catalyze the riboflavin oxidation and of copper to catalyze the destruction of ascorbic acid. When milk contained the lower riboflavin value, no oxidized flavor could be detected until the fourth day of dark refrigerated storage. The milk with the higher riboflavin content developed an oxidized flavor on the second day of storage. There was an approximately inverse proportion between the riboflavin and the ascorbic acid content in each sample, within the range previously stated. Also, during taste-panel studies of the oxidized flavor, a distinct odor developed together with the flavor deterioration and, in some samples, acceptability ratings could be defined as accurately by odor as by taste.

A continuation of these studies within recent months led to a possible explanation of the mechanisms which cause the deterioration of ascorbic acid, riboflavin, and flavor in milk on exposure to light, air, and storage. When the two isolated vitamins (ascorbic acid and riboflavin) and the two isolated minerals (copper and iron) were dissolved separately in pasteurized milk solutions, employing the procedure of Hand (11), the ascorbic acid and riboflavin proved to be fairly stable constituents in dark refrigerated storage over a 10-day period. The ascorbic acid solution did not exhibit any marked deterioration on exposure to air and light until the copper solution was added. The addition of the riboflavin solution merely accelerated the destruction of the ascorbic acid, and was unnecessary for the initiation or continuation of the reaction.

An attempt was made to prepare a riboflavin-free milk (11) which could be subjected to oxidized-flavor studies, but milk treated to remove the vitamin tasted so strange that "oxidized flavor" as such was considered but a minor defect. It was not possible to detect the progressive development of the oxidized flavor under this condition.

An ascorbic acid-free milk was readily prepared by exposing frozen pasteurized milk in flat enameled pans, 1 inch deep, to bright sunlight for 25 minutes. Ascorbic acid analyses were made by the direct titration method using the sodium 2,6-dichlorobenzenoneindophenol dye. Such milk did not develop an oxidized flavor until after the fourth day of dark refrigerated storage. When, however, such sunlight-exposed milk was only chilled, omitting light-protective measures entirely, the oxidized flavor could be detected at the end of the third day. It would thus appear that riboflavin must be

mainly the cause of the development of the oxidized flavor and not ascorbic acid.

A further investigation of the riboflavin activity was therefore advanced. Riboflavin in milk represents an intermediate complex, as in plant and animal tissues this vitamin is almost entirely combined with protein. In urine, the vitamin is all in the free state, whereas in milk it is partly free and partly combined. By using the fluorometric method of analysis (1) with and without hydrolysis, it was observed that two-thirds of the riboflavin present in fresh pasteurized milk is in the free form. The one-third which is combined represents an enzyme complex consisting of riboflavin, 2 molecules of phosphoric acid, one molecule of adenine, and a specific protein molecule.

In milk, there are present mainly 2 such yellow enzymes (23): diaphorase and xanthine oxidase, each one possessing a slightly different protein structure but otherwise retaining a structural similarity to each other. Both enzymes are oxidative. As the name, xanthine oxidase, indicates, it is capable of oxidizing xanthine or purine derivatives to uric acid. It also oxidizes a variety of aliphatic and aromatic aldehydes to the acid stage. The diaphorase (actually 2 exist) oxidizes the reduced forms of coenzymes 1 and 2 which act to decompose carbohydrates and release niacinamide from molecular combination. In the degradation of carbohydrates, many of the aldehydes are formed which are then oxidized by the xanthine oxidase. When xanthine oxidase acts upon its substrates in the presence of air, *hydrogen peroxide* is formed (23). This explains in part the accelerating action that the riboflavin complex has upon the destruction of ascorbic acid. However, the hydrogen peroxide *inhibits* the breakdown of the riboflavin enzyme unless catalase is present to destroy it, and milk contains only traces of catalase. Despite the fact that catalase is one of the most effective enzymes known, the peroxide present under these conditions is capable of destroying this enzyme completely. The yellow enzymes, however, ultimately yield their protein and riboflavin in free form on exposure to light. The writer observed that the most destructive radiations were in the range of 445-460 millimicrons.

Based on the information obtained that riboflavin was mainly responsible for the development of the oxidized flavor in milk, it was recalled that certain visual disturbances (dimness of vision) could be cured by riboflavin within a short time (21). The evidence indicated, therefore, that riboflavin might sensitize the retinal cells through conversion by light of substances present into a compound which is capable of stimulating the optic nerve. Thus, riboflavin can be considered a receptor pigment which can elicit a phototropic response (photo-oxidation) in compounds other than itself. Galston and Baker (9) demonstrated such a reaction during a study of the mechanism of light action on plant growth. They found that riboflavin could sensitize the photo-oxidation of various indole-containing compounds including the amino acid, tryptophane. The authors showed that the oxidation took place even when the amino acid was included within a protein molecule. In fact,

Galston found that all the enzymes tested were inactivated when suspended in riboflavin solutions subjected to moderate intensities of light. It is, therefore, reasonable to visualize the manner in which protein chains from milk and from the riboflavin enzymes can be readily oxidized and inactivated by way of the tryptophane link. Furthermore, oxidation of tryptophane gives rise to indole and indole derivatives, the taste and odor of which are well known.

Once the protein molecule is broken, the other amino acids are released to greater or smaller degree, thereby producing the sulfhydryl groups of cystine and methionine (5). The production of hydrogen sulfide under such circumstances is a natural sequence and this gas, even in the minute quantities formed, can be detected with moistened lead acetate paper. The degree of hydrolysis in milk when tryptophane is oxidized may be approximated by noting that the milk contains about 3.5 percent protein. The tryptophane content is 2.0 percent of the milk protein; methionine is 2.8 percent of this protein and cystine is 1.2 percent (5). While the usual proteolytic action in milk can produce protein fragments of peptide length, the tryptophane-sensitized oxidation may shorten these chains even more.

Another light-sensitive enzyme in cow's milk was described by Kay (16) and Krukovsky (17). The lipase (tributyrinase) Kay studied proved to undergo the same type of photo-destruction in the presence of riboflavin as that mentioned by Galston (9). In this instance, however, the reaction can give rise to the formation of butyric acid. The fact that this lipase is destroyed within 3 hours after exposure explains why no greater quantity of butyric tastes and odors are produced. Kay indicated that this lipase, as well as ascorbic acid, underwent continued decomposition in the presence of riboflavin even when the milk was returned to dark refrigerated storage after a short initial light exposure.

Because of the marked complexity of the activity of riboflavin (free and combined) in milk, there is a similar complexity of origins for the production of the oxidized flavor, some of which are:

1. Diaphorase oxidation of reduced coenzymes, the products of which are carbohydrate derivatives including aldehydes and pyridines of the niacinamide type.
2. Xanthine oxidase oxidation of aliphatic and aromatic aldehydes to the acid stage, production of uric acid and a peroxide.
3. Lipase action responsible for the production of butyric derivatives.
4. Photo-oxidation of tryptophane, producing indole and indole derivatives.
5. Proteolytic action giving rise to the sulfhydryl groups and hydrogen sulfide.
6. Bacterial action.

Thus, the initial concentrations of the enzymes and vitamins in the milk, together with light exposure, storage conditions, aeration, and sanitation, will largely determine the stability of that milk.

## Discussion

Through the use of this information, it may be possible to evaluate the controversial statements cited

previously with some degree of correlation:

In general, the work of Hand and coworkers (11) was verified except for the declaration that riboflavin *alone* was responsible for the sensitivity of ascorbic acid to light. The presence of copper, dissolved oxygen, and sunlight catalyzed the decomposition of ascorbic acid beyond the dehydro-stage, forming peroxide (13). Because the deterioration of the ascorbic acid did not cease when the sample was placed in dark refrigerated storage, it was concluded that the peroxide present was sufficient to activate a chain reaction which slowly continued the oxidative destruction. There can be no doubt that the photo-sensitization of ascorbic acid in the presence of riboflavin is the principal reaction, but this reaction is not the only accelerator of ascorbic acid inactivation.

Concerning the observation by Stamberg and Theophilus (22) that the photo-oxidation of riboflavin was greater in raw milk than in pasteurized milk, the writer found that phosphatase could hasten such destruction through ability to oxidize the two types of yellow enzymes at the phosphoric acid linkages, thereby releasing free riboflavin from an otherwise fairly stable complex. As is well-known, the phosphatase is completely destroyed by pasteurization, leaving the combined riboflavin complex unbroken through any action by this enzyme.

The reports by Krukovsky and Guthrie (18, 19) that ascorbic acid in milk accelerated the development of oxidized flavor must be carefully considered in conjunction with the work of Chilson (2). It is not sufficient to conclude that partial oxidation of the ascorbic acid might cause the acceleration rather than the inhibition of the oxidation of milk fat, for example, and that further rapid oxidation of the ascorbic acid might be expected to eliminate its pro-oxidant effect. This would lead to the assumption that the completeness and speed of the ascorbic acid oxidation would eliminate oxidized flavor formation. Since oxidized flavor ultimately occurs, even after the rapid oxidation of ascorbic acid, it is difficult to explain this flavor defect in terms of ascorbic acid action alone. Also, the mixture of the reduced and dehydroascorbic acids which Krukovsky (18, 19) proposed as the accelerator of oxidized flavor appears to rely mainly upon the o-quinoid-type structure of dehydroscorbic acid for the oxidative action. At the normal pH of milk, 6.6, the dehydroascorbic acid is rapidly converted to an irreversible, physiologically inactive product. The speed of this reaction may be considered only a minor point in favor of the prevention of oxidized flavor.

However, the action of peroxides upon fats to cause "reversion" is well known. Thus, the oxidized flavor in milk is acknowledged as being partly due to the peroxide action upon the milk fat. The peroxide quantities released from the ascorbic acid oxidation and the xanthine oxidase activity are exceedingly minute (0.002%), however, when compared with the 0.1% or more of hydrogen peroxide used to preserve milk experimentally. Duplication by the writer of the work of Chilson (2),

with higher peroxide preservative concentrations, revealed that it is possible to oxidize the entire ascorbic acid present in milk within minutes, and under these same conditions, sterilize the fluid and oxidize much of the free riboflavin to lumichrome. The lumichrome is capable of photosensitizing the oxidation of tryptophane and other components, but performs this activity at a much slower rate than riboflavin itself (9b). Thus, the development of the oxidized flavor is delayed but not eliminated through the use of hydrogen peroxide.

The fortification of milk with ascorbic acid such as was done by Chilson (2) and Hand (11) serves to remove, temporarily, the available oxygen required for the photo-sensitizing reaction of riboflavin. Chilson stated that while such fortified milk did lose all of its ascorbic acid rapidly when exposed to sunlight or to a solution containing peroxide, it did not develop oxidized flavor until the fifth day of storage. Thus, a temporarily protective quality seems to have been conferred upon the milk by either the excess ascorbic acid or the peroxide treatment. It appears that the keto-gulonic acid breakdown products from ascorbic acid are of a peroxide type and act in a manner analogous to hydrogen peroxide. On the other hand, it is difficult to conceive of the keto-gulonic oxidation products functioning as antioxidants. Fortification of milk with ascorbic acid therefore appears to be most advantageous when that milk is retained in dark refrigerated storage.

With reference to the work of Holmes (14) on the riboflavin enrichment of mare's milk to hasten the ascorbic acid destruction, it is necessary to note the comparative values of both mare's and cow's milk as listed in table 1.

Analyses for water, fat, protein, sugar, ash compared favorably with Sherman (20) for both types of milk. The ascorbic acid and riboflavin values are averages for cow's milk and were determined by the writer (6), whereas the ascorbic acid average for mare's milk was obtained from Holmes (14). The riboflavin content of mare's milk was difficult to ascertain (6) because of the wide variation observed, but very few samples contained more than 0.02 mg. per 100 ml. An average of 54 percent of the riboflavin in mare's milk was in the combined form.

A survey of the comparative data on mare's and cow's milk shows the fat, protein, and vitamin values to be significant factors. The writer could detect no oxidized flavor in pasteurized mare's milk which had been stored in a dark refrigerator

TABLE 1.—ANALYSIS OF MARE'S AND COW'S MILK

| | *Water (percent)* | *Fat (percent)* | *Protein (percent)* | *Sugar (percent)* | *Ash (percent)* | *Ascorbic acid (mg/100 ml.)* | *Riboflavin (mg/100 ml.)* |
|---|---|---|---|---|---|---|---|
| Cow's milk.. | 87.00 | 4.00 | 3.35 | 4.90 | 0.75 | 1.5 | 0.15 |
| Mare's milk. | 90.75 | 1.20 | 2.00 | 5.70 | 0.35 | 13.5 | 0.02 |

for 8 days, whereas cow's milk had an oxidized flavor after 2 days of identical storage. Apparently, the high ascorbic acid content presented conditions typical of an unusually well-fortified milk. The low fat content of the mare's milk was also a factor in maintaining its superior storage qualities. The extremely low riboflavin value in mare's milk coupled with the low protein content, provided a poor basis for the photo-sensitized reaction between riboflavin, ascorbic acid, and tryptophane. Thus, one would expect that dark refrigerated storage of mare's milk would bring about very little deterioration of riboflavin and flavor, and such was the case. However, based on the previously discussed peroxide activated chain reaction, it is not surprising to note that Holmes found ascorbic acid continuing to deteriorate even in the dark. His conclusion, therefore, that riboflavin was not the principal factor in causing the rapid disappearance of ascorbic acid from milk stored in the dark at 10° C. (14) seems only partially tenable as both ascorbic acid and xanthine oxidase deterioration give rise to peroxide. The riboflavin is still a potent accelerator of this reaction, as there were short intervals of light exposure and no precautions were taken to remove available oxygen from the samples initially.

Holmes (14) illustrated the course of ascorbic acid deterioration in the presence of riboflavin-enriched mare's by three curves: one for normal milk and two for milk to which riboflavin had been added, as previously described. The first curve appears to be sharply divergent from the other two. Nevertheless, all three curves are very nearly parallel after the first day. Thus, as long as free riboflavin is present, particularly after the unavoidable light exposures in preparing the samples for storage and for analysis, the ascorbic acid loss is comparatively sharp and precipitous for the first day. Then, on the second day, the riboflavin complex, being fairly stable, does not induce a very great ascorbic acid loss until hydrolysis of this complex occurs. Once this has taken place, free riboflavin is again available for furnishing the means for further destruction of the ascorbic acid.

## Summary and Conclusions

1. Factors which have been found to influence the stability of milk include: ascorbic acid (reduced and dehydro), riboflavin, lipase, xanthine oxidase, diaphorase, copper, iron, dissolved oxygen, light, and temperature.

2. Riboflavin accelerates the destruction of ascorbic acid in milk, but is unnecessary for the initiation or continuation of the reaction.

3. Riboflavin is mainly responsible for the development of the oxidized flavor in milk, whereas ascorbic acid is only secondarily so.

4. In fresh pasteurized milk, two-thirds of the riboflavin is in the free form. The other third is combined as an enzyme-complex consisting of riboflavin, 2 molecules of phosphoric acid, one molecule of adenine, and a specific protein molecule, the protein differing for the particular enzyme concerned (xanthine oxidase and diaphorase).

5. Riboflavin is responsible for the photo-oxidation of tryptophane in the milk protein, producing indole derivatives.

6. Sulfhydryl groups and hydrogen sulfide are detectable in milk undergoing light and storage deterioration.

7. The destruction of ascorbic acid appears to be a chain process which continues to completion once initiated in the milk, whereas the riboflavin loss can be markedly delayed by storing the milk, de-aerated, in a dark refrigerator.

8. A peroxide action upon the milk fat has been traced to the action of xanthine oxidase and ascorbic acid oxidation.

9. Fortification of milk with ascorbic acid results in the stabilization of the milk by the ascorbic acid functioning as a antioxidant which removes dissolved oxygen from the solution.

10. The use of peroxide in the preservation of milk is based upon sterilizing action, degradation of fatty oxides, oxidation of riboflavin to lumichrome, and the oxidation of ascorbic acid irreversibly to physiologically inactive products which do not bring about further objectionable changes in the milk.

11. The slower deterioration of mare's milk as compared with cow's milk may be due to the fact that mare's milk contains approximately ten times the amount of ascorbic acid and about one-eighth the riboflavin of cow's milk. The riboflavin in mare's milk is combined to a greater extent (54%) than the same vitamin in cow's milk (33%).

12. Milk contains a lipase which is responsible for the production of butyric acid.

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# REACTION OF EPOXIDES WITH MERCAPTANS

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Epoxides react with a variety of anions such as mercaptide, alkoxide, and phenoxide, and with a number of molecular species possessing unshared electron pairs such as mercaptans, alcohols, phenols, ammonia, and amines. In general, two modes of addition are possible in the reaction of an unsymmetrical epoxide with any of these reactants, the reaction of epichlorohydrin, 1-chloro-2, 3-epoxypropane, with a mercaptan, for example, conceivably yielding either a 1-alkylthio-3-chloro-2-propanol or a 2-alkylthio-3-chloro-1-propanol:

$$RSH + ClCH_2\text{-}CH\text{-}CH_2 \rightarrow ClCH_2\text{-}CHOH\text{-}CH_2\text{-}SR \textit{ or}$$

$$ClCH_2\text{-}CH(SR)\text{-}CH_2OH$$

This reaction was first investigated by Nenitzescu and Scarlatescu (1), who concluded that the secondary alcohol is formed. Their conclusion was based upon the observation that dehydrohalogenation of the addition product yields the same product obtained directly from epichlorohydrin and a mercaptide, i.e.,

$$RSH + ClCH_2\text{-}CH\text{-}CH_2 \rightarrow RS\text{-}CH_2\text{-}CHOH\text{-}CH_2Cl \xrightarrow{KOH} RSK + ClCH_2\text{-}CH\text{-}CH_2 \rightarrow RS\text{-}CH_2\text{-}CH\text{-}CH_2$$

(I) (II)

Gilman and Fullhart (2) observed that the above sequence does not necessarily preclude the primary alcohol structure. They then demonstrated conclusively that addition of a mercaptan to styrene oxide yields a secondary alcohol structure. However, the proof of addition to styrene oxide is not necessarily valid when applied to epichlorohydrin. The secondary alcohol structure postulated by Nenitzescu and Scarlatescu was verified, however, by hydrolysis of the addition product and subsequent periodic acid oxidation of the resulting glycol (3).

$$RS\text{-}CH_2\text{-}CHOH\text{-}CH_2Cl + H_2O \rightarrow RS\text{-}CH_2\text{-}CHOH\text{-}CH_2OH + HCl$$

Periodic acid is a specific reagent for the cleavage of vicinal dihydroxy compounds and this reagent reacted smoothly with the glycol to yield formaldehyde by fission. Had the addition product been of the primary alcohol structure, hydrolysis would have yielded a 2-alkylthio-1,3-propanediol and periodic acid oxidation would not have occurred.

The 1-alkylthio-2, 3-epoxypropane (II) obtained by dehydrolhalogenation of (I) provided additional opportunity for study of addition at an epoxide bond. Reaction of (II) with a mercaptan again yielded a secondary alcohol, a 1,3-bis(alkylthio)-2-propanol (III) as shown by the behavior of the oxidation product of (III), a 1,3-bis(alkylsulfonyl)-2-propanol (IV), on hydrolysis.

$$RSH + RS\text{-}CH_2\text{-}\underset{\diagdown\,O\,\diagup}{CH\text{-}CH} \rightarrow RS\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}SR \xrightarrow{H_2O_2} RSO_2\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}SO_2R$$

(II) (III) (IV)

A disulfone of the type illustrated by (IV) would be expected to undergo virtually no hydrolysis according to Stuffer's rule (4) and relatively little hydrolysis was observed experimentally. The alternative structure, 2,3-bis(alkylthio)-1-propanol on oxidation would yield a so-called gamma disulfone which would characteristically undergo hydrolysis according to the above rule.

Addition of an alcohol to (II) paralleled the addition of a mercaptan and a secondary alcohol is formed.

$$ROH + RS\text{-}CH_2\text{-}\underset{\diagdown\,O\,\diagup}{CH\text{-}CH_2} \rightarrow RS\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}OR$$

(V)

The structure of (V) was proved by demonstrating its identity with the substance obtained by reaction of a potassium mercaptide with a 1-alkoxy-3-chloro-2-propanol of established structure (5).

Since both alkylthio and alkoxy groups are necessarily situated on primary carbon atoms, the hydroxy group is present on a secondary carbon atom.

$$RO\text{-}CH_2\text{-}CHOH\text{-}CH_2Cl + KSR \rightarrow RO\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}SR$$

(V)

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# SOME FACTORS INFLUENCING THE SUSPENSION POLYMERIZATION OF STYRENE-DIVINYLBENZENE MIXTURES

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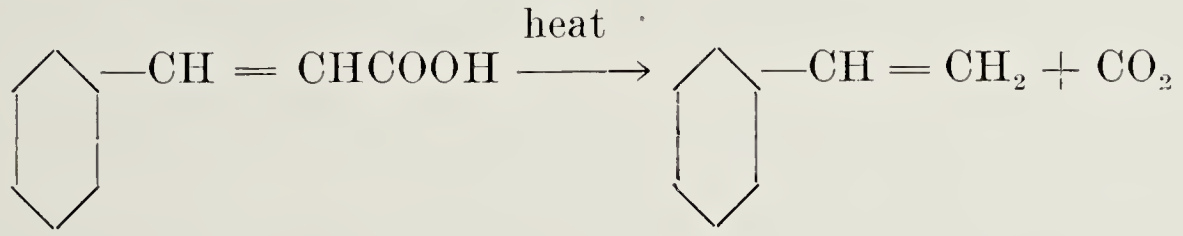
Styrene, which occurs in liquid storax, is a fragrant, honey-like substance found in various plants, and was first isolated by Bonastre in 1831. Several methods of synthesizing the compound have been developed since that time. The decarboxylation of cinnamic acid by distilling is said (1) to produce styrene in yields of 38 to 41 percent.

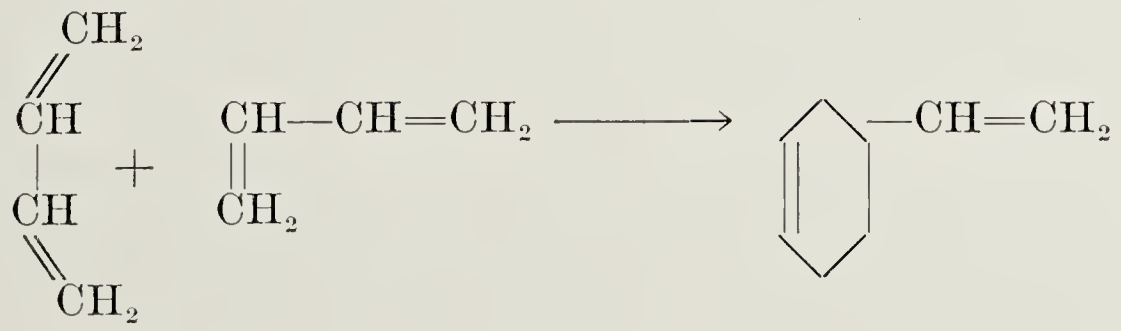


Heating of acetylene produces some styrene in addition to benzene:

$$4CH{\equiv}CH \xrightarrow{\text{heat}} C_6H_5CH = CH_2.$$

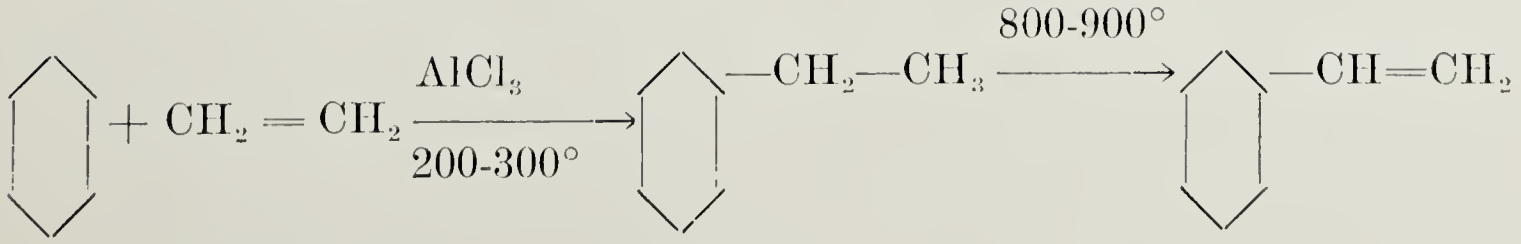
The dehydration of $\beta$-phenylethylalcohol also yields styrene: $C_6H_5CH_2\text{-}CH_2OH \rightarrow C_6H_5CH = CH_2 + H_2O$.

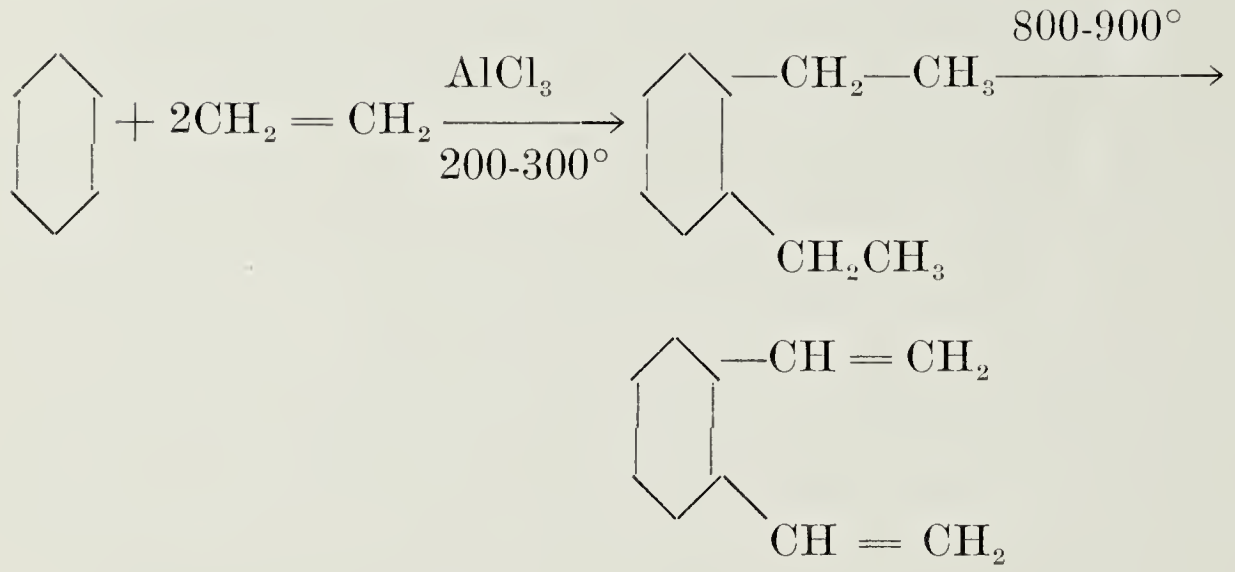
A method worked out by Weizmann and co-workers in 1948 starts with butadiene formed from petroleum. This dimerizes through a Diels-Alder reaction:



The dehydrogenation of the vinylcyclohexene then yields the styrene. This is said to be more effective than coal pyrolysis as a source of styrene.

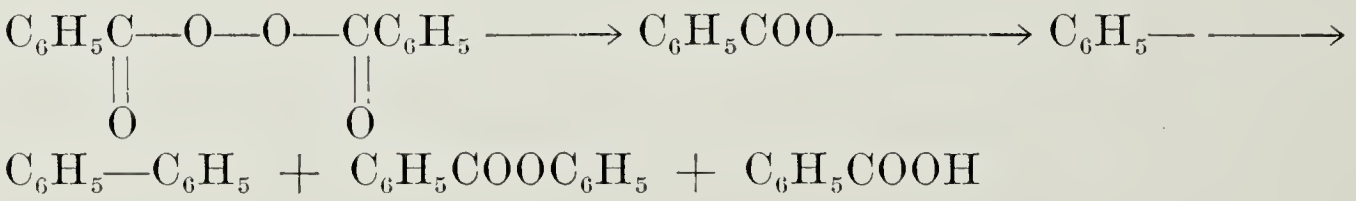
The present commercial method used by Dow and other manufacturers (2) involves the vapor-phase union of benzene and ethylene to produce ethylbenzene—along with some diethylbenzene—followed by dehydrogenation:



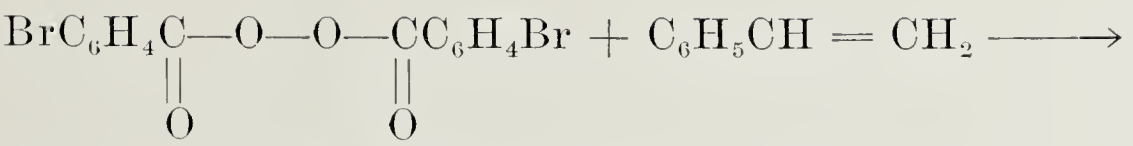



The polymerization of styrene was probably observed before styrene had been isolated. Evidence for this lies in the name applied to certain trees of the witch hazel family. These trees, of the genus Liquidambar, exude styrax. The first light-induced polymerization of styrene seems to have been the work of Blyth and Hofmann about 1845 (3) although Simon (4) is supposed to have polymerized it by heating it to 200° about six years earlier. This polymer, possibly the first of the synthetic resins, did not come into any practical use in this country until 1937, when a suitable method of producing monomer at low cost was worked out. Because the manufacture of synthetic rubber has resulted in a large capacity to produce styrene, the cost has been reduced to a point where it is the lowest priced transparent resin. The more common polystyrene resins are sold as molding granules.

The polymerization of styrene is catalyzed by oxygen, various oxidizing agents—notably peroxides—and by light. The reaction is rapid in an emulsion, such as 5 percent sodium oleate, and leads to the formation of high molecular weight polymers. The absence of low molecular weight products and the added fact that distyrenes and tristyrenes do not polymerize to polystyrene suggests a chain reaction mechanism involving free radicals. If dibenzoyl peroxide is used as catalyst it gradually decomposes thus:



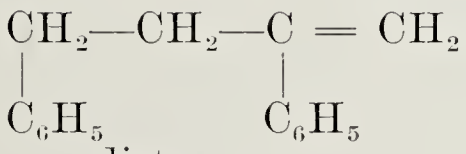

One evidence for the formation of free radicals is the transient color appearing during the early stages of the polymerization. That these free radicals become attached to at least one end of the chain is shown when a marking group such as an atom of bromine, present in the peroxide, can be detected in the polystyrene:



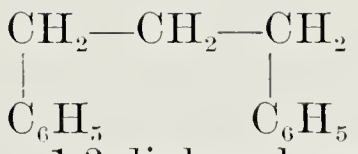
(1) $BrC_6H_4COOCHCH_2CHCH_2$ — etc.
$C_6H_5$ $C_6H_5$

(2) $BrC_6H_4CHCH_2CHCH_2$ — etc.
$C_6H_5$ $C_6H_5$

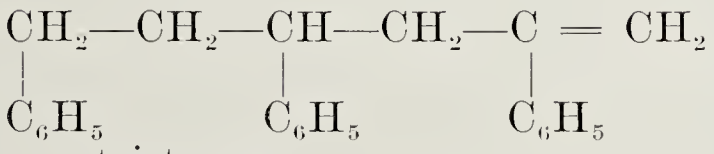
The structure of polystyrene can be deduced from the four products of destructive distillation (in addition to styrene itself):



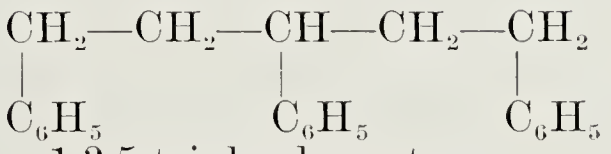
distystyrene



1,3-diphenylpropane

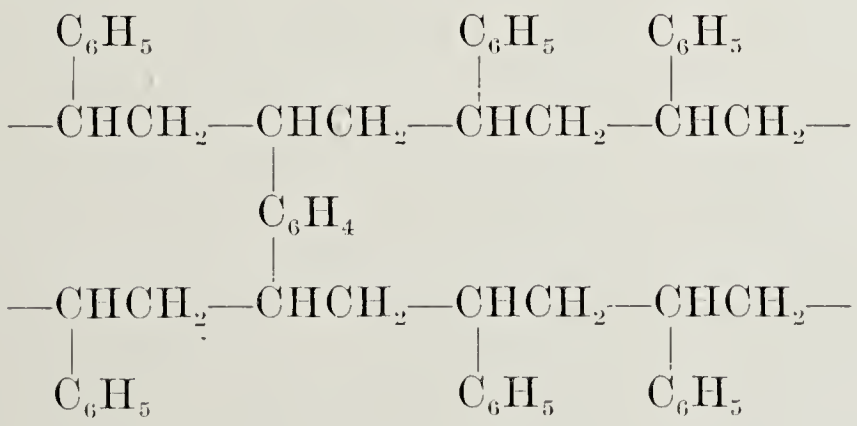


tristyrene



1,3,5-triphenlypentane

Like the other vinyl resins styrene groups are joined head-to-tail to form long chains. As is to be expected, these are thermoplastic. However, minute amounts—as little as 0.002 to 0.003 percent—of divinylbenzene added prior to polymerization yields a relatively nonthermoplastic, insoluble resin. The effect has been compared to that of sulfur in the vulcanization of rubber. Cross-linked polymers result from the presence of a second functional group attached to the benzene ring:



If the copolymerization of styrene and divinylbenzene is carried out in aqueous suspension in the presence of certain stabilizers, the product may show up in the form of beads or "pearls." Fryling and Harrington (5) and Hohenstein and Mark (6) point out that suspension polymerization is in reality bulk polymerization on a small scale. Actually only a few monomers, mostly vinyl compounds, seem to possess properties suitable for suspension polymerization.

Taylor (7) suggests that mechanical agitation subjects the monomer to a viscous drag causing elongation to a thread-like form with subsequent degeneration into drops. By means of the reverse process of coalescence, the drops tend to revert to a monomeric mass. Clusters of droplets, not fused but held together by weak residual forces, tend to disperse with agitation. Snell (8) points out that effective surface-active agents alone are capable of deflocculating the aggregates of droplets.

The effect of the suspension stabilizer becomes most important at the onset of polymerization when the droplets become tacky. A protective monomolecular film, resulting from the selective adsorption of stabilizer at the interface, prevents cohesion of monomer. Hutchinson and Staudinger (9) indicate that the "tacky" stage encountered here is absent or much less pronounced in the polymerization of other vinyl compounds such as the vinyl esters and the acrylic ester type of compound. The tendency toward stickiness makes it more difficult to control globular diameter as the diameter of the beads increases. The largest beads may be as much as 50 times the size of the smallest, and uniformity is particularly difficult to get when beads of more than 1 mm. diameter are desired.

Winslow and Matreyek (10) tried both inorganic and organic suspension stabilizers. Of the former, bentonite and tricalcium phosphate produced opaque beads by surface roughening. The organic dispersants used were all typical hydrophilic polymers:

Methyl cellulose
Polyvinyl alcohol
Polyvinyl methylether
Polyethylene glycol
Polymethacrylic acid
Carboxymethyl cellulose
Starch
Gelatin
Apple and citrus pectins
Sodium alginate

Using 40-50 percent divinylbenzene mixtures they found polyvinyl alcohol to be among the most effective stabilizers.

The polymerizations described in this paper were carried out in a 2-liter pyrex resin kettle with a three-neck ground-glass cover. The kettle was suspended in a water bath—a 4-liter beaker—heated by an electric hot plate. A variable speed stirrer of the cone-drive type was used. A reflux condenser and thermometer completed the required equipment.

The suspension stabilizer was stirred into 1500 ml. of water while the latter was being heated. When the specified temperature (95° in the early runs, 80° or even room temperature in the later runs) was reached, the monomer containing the dissolved dibenzoylperoxide was added in one portion. Stirring could be stopped during the addition, but after the induction period (5 to 10 minutes at 95°) continuous stirring was required until polymerization was nearly complete. This induction period could be shortened by distilling the monomer in order to remove the inhibitor, tert-butyl catechol. No other detrimental effect of the inhibitor was observable, however.

Polymerizations were complete in two to two and one-half hours. The increase in density of the beads so

that they would sink when the stirring was interrupted showed the reaction to be finished. Closer control of specific gravity could be obtained by using brines of known specific gravities instead of water for the dispersion medium.

The beads were filtered while hot through a 100-mesh screen, thoroughly washed, and dried at 105° for 3 hours or longer. When dry the beads were weighed and screened to determine size distribution. Screening was difficult because the dried beads tended to acquire an electrostatic charge. Dusting with graphite will eliminate the problem, although cautiously breathing on the beads is simpler and avoids the blackening caused by graphite.

In all, some one hundred polymerizations were carried out. Of the stabilizers listed by Winslow and Matreyek, the following were tried:

Carboxymethyl cellulose
Polyvinyl alcohol
Sodium alginate
Starch
Gelatin

In addition glucose, casein glue, animal glue, soap solution, and such commercial products as Antarox and Tween (polyoxyethylene sorbitan monooleate) were tried. Of this list only animal glue and gelatin gave desirable results and the latter was used in most of the polymerizations. Edible-grade gelatin did not seem any more effective than technical-grade. Styrene monomer was commercial-grade stabilized with tert-butyl catechol. The divinylbenzene, available from Dow Chemical Company, was of two grades, 20-25 percent and 40-50 percent. Typical compositions given were as follows:

| | Percent 20-25 | Percent 40-45 |
|---|---|---|
| Divinylbenzene | 23.4 | 43.7 |
| Ethylvinylbenzene | 30.7 | 43.5 |
| Styrene | 10.4 | .... |
| Non-polymerizables | 35.5 | 12.0 |

For the most part the beads were uniformly spherical (fig. 1), but occassionally, in the larger size ranges oval beads and fused beads were observed. Fusion was particularly noticeable when stabilizers other than gelatin or glue were employed.

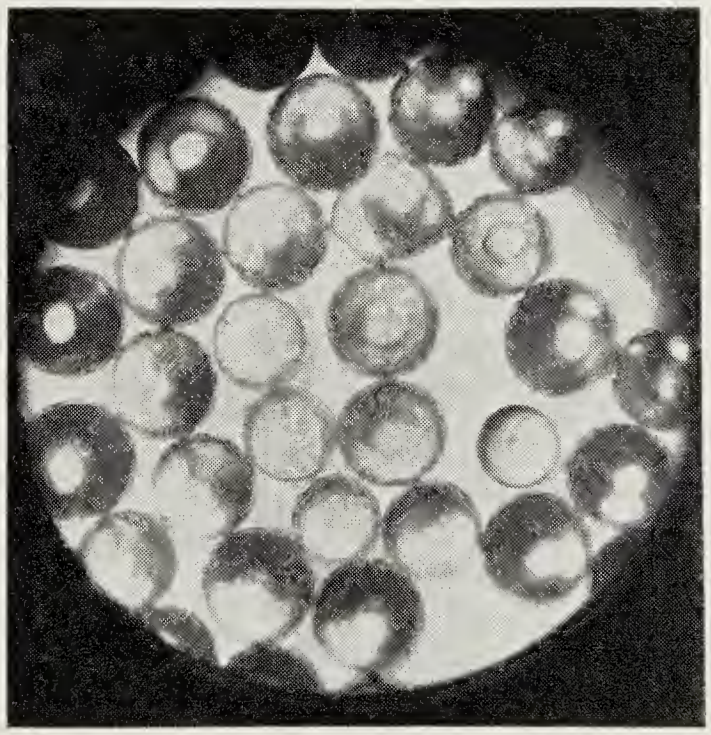


FIG. 1.

At the start a stabilizer concentration of 1 percent was used. This was gradually decreased without ill effect until only 0.5 grams of gelatin was used in 1500 ml. of water, a concentration 0.033 percent. An attempt to reuse the gelatin gave poor results. The beads showed opacity and considerable powdery material was present.

The ratio of catalyst to monomer was held at 1 percent, and the ratio of monovinylbenzene (styrene + ethylvinylbenzene) to divinylbenzene was 10 to 1 in most runs.

The amount of monomer used seemed to influence the size of the beads (fig. 2). The amount of monomer could be increased from 50 grams per 1500 ml. of water to 300 grams and even higher.

The most important single factor other than the type of stabilizing agent was the stirring. Both the rate of stirring and the type of stirrer used influenced the size and appearance of the product. Too slow stirring lets the monomer droplets coalesce and form large chunks of polymer. Too rapid stirring breaks the monomeric liquid into such fine droplets that microscopic beads result. In general smaller beads result from more rapid stirring (fig. 3).

No statement about stirring rate can be made without specifying the type of stirrer used. Four types used were: 4-blade propeller types, one with blades directed for upward and one with blades for downward motion of liquid; spiral type; and anchor type designed to fit exactly the resin kettle. The down-draft stirrer gave smaller beads than the up-draft type, even at lower speed. The spiral type could not be speeded up sufficiently to prevent coalescence. The anchor stirrer was so efficient at moving the entire body of the liquid that the stirring rate could be reduced to 120 r.p.m., whereas the rate used in the propeller type stirring varied between 250 and 450 r.p.m.

A student experiment in pearl polymerization has been worked out which, unlike one described in the literature (11), does not require 7 to 8 hours of continuous stirring or redistillation of monomer. The apparatus, with the possible exception

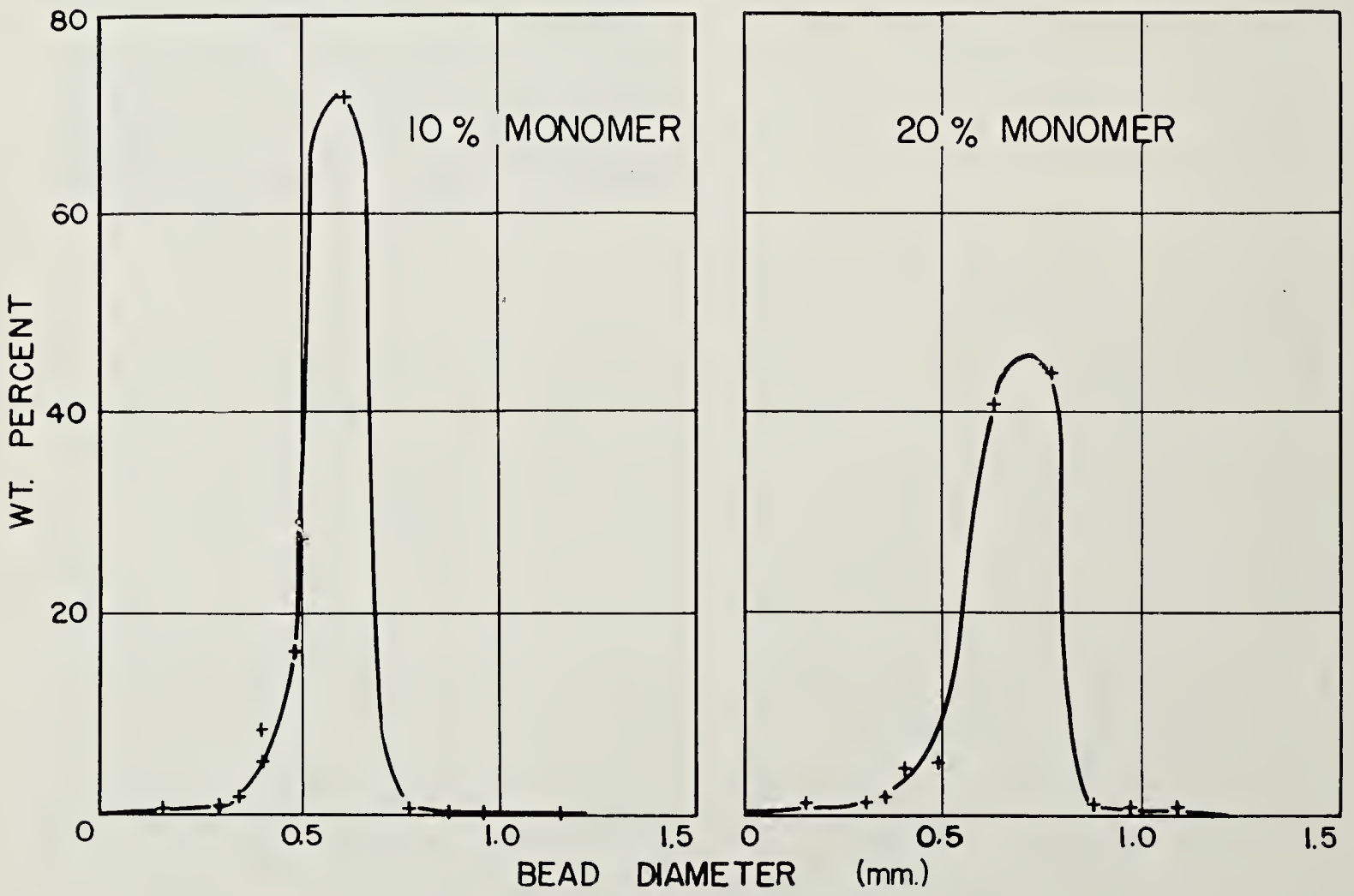



Fig. 2.

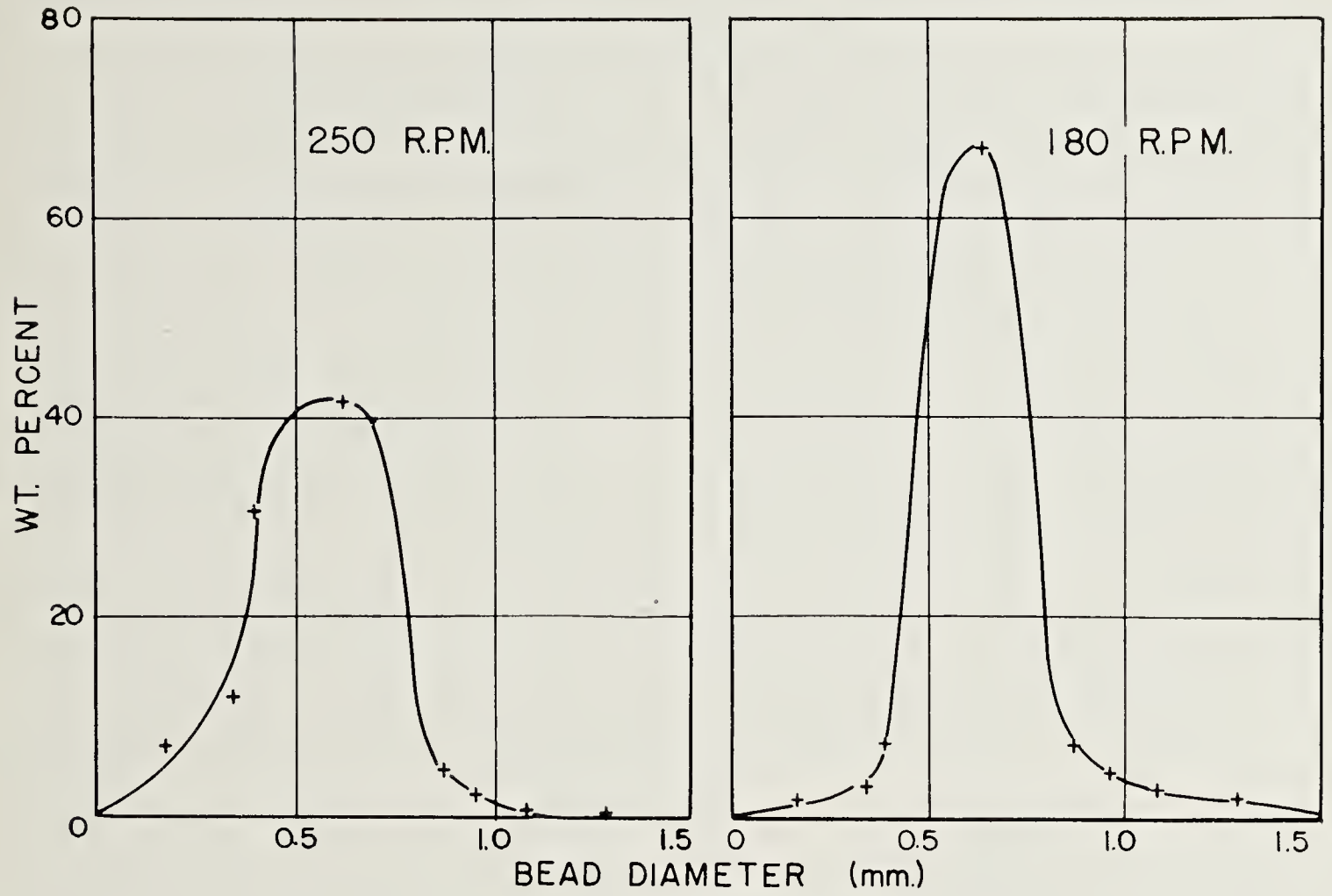



Fig. 3.

of the stirring motor, makes use of equipment normally found in the student's locker. The directions, which were given out to the students in mimeographed form, are as follows:

Note: It is imperative that the polymerization be carried through in one period. Set up the apparatus during one period, label it, and start the reaction at the beginning of the next.

In a 500 ml. 3-neck, round-bottom flask equipped with a stirrer, thermometer, and condenser place a suspension of 0.1 to 0.2 gm. of gelatin in 300 ml. of water. The flask is then set in a water bath. (A 1-liter beaker should suffice. It is desirable to put a few glass beads or boiling chips in the beaker to prevent bumping.)

Adjust the stirring rate to approximately 200 r.p.m. and heat the water bath. Meanwhile measure out between 0.1 and 0.2 grams of benzoyl peroxide and dissolve it in a mixture of 10 ml. of styrene and 2.5 ml. of divinylbenbene. When the temperature of the water suspension reaches 75-80° add the mixture of monomer and catalyst. Do not discontinue stirring after this until reaction is complete.

The temperature should rise to 97-98°. Continue at this temperature for 1 hour, stop stirring, remove water bath and, when sufficiently cool to handle, pour entire contents of flask onto a Büchner funnel. Wash 2 or 3 times with hot water, suck dry, and place polymer in a small flask in an oven set at 105°. Examine some of the dried product under the microscope; hand in the remainder in a small stoppered test tube.

Questions:

1. Could you observe when gelation occurred? How?
2. What happens to the specific gravity of the material during the polymerization?
3. Describe the product. Are the beads clear? What color are they?
4. What electrical properties do you observe?

The beads obtained were generally small but fairly uniform and in good yield. Yields, based on monomer, usually run over 90 percent. In a few cases, when the stirring was accidentally interrupted, the polymer set up as a mass.

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# GEOGRAPHY

## LAND-USE ASSOCIATIONS IN THE ORCHARD ECONOMY OF SOUTHERN ILLINOIS

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Commercial orchards of peaches and apples are significant in the agricultural economy of six areas in southern Illinois. The accompanying may (fig. 1) shows these two orchard crops are concentrated near (1) Metropolis and (2) Villa Ridge, the most southerly orchard districts in the state and two of the smallest in southern Illinois, (3) Anna-Cobden, the most important in southern Illinois, (4) New Burnside, which ranks third, and last the two most northerly in southern Illinois, (5) Centralia, number two in importance, and (6) the Sesser district, the smallest of all.

Orchard farmers who derive their primary income from peaches and apples also devote some energy, land, and capital to other cash crops. The wide fluctuations in production and sale prices of peaches and apples are all too characteristic of southern Illinois orcharding. When the markets are good they often have no crop, orchardists say, and when they have a good crop, there is no market. It is only good insurance, if not good horticultural practice, for an orchardist to spread his sources of income and to attempt to combine other land uses which will fit in with his fruit business.

The six districts mentioned differ from each other, not only in the relative importance of peaches or apples, but also in the type of land use associated with orcharding (fig. 1). Each orchard area has its own land use associations as well as its orcharding character.

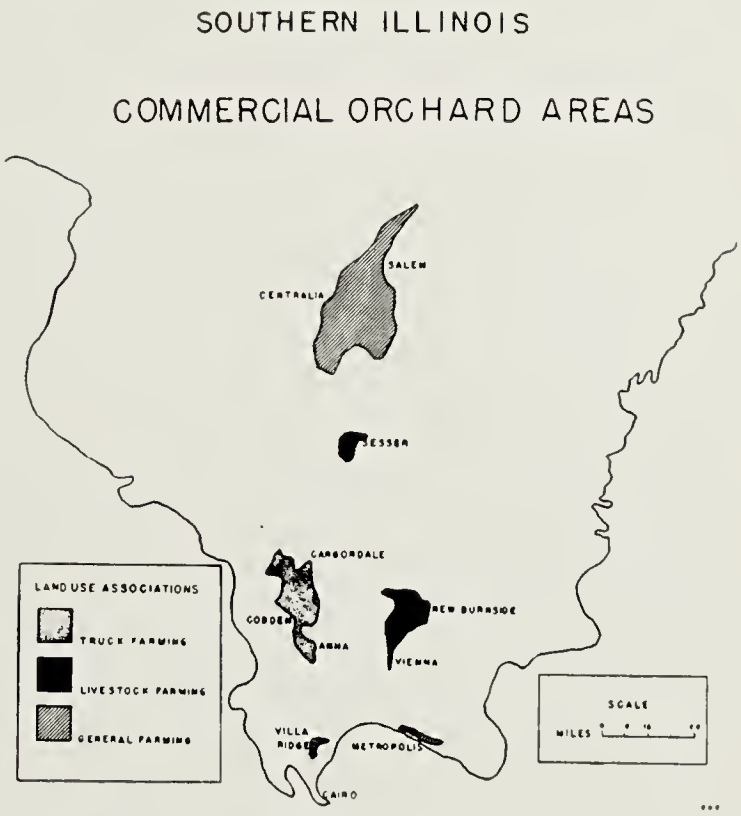


FIG. 1.

The Metropolis and Villa Ridge districts comprise only about 70 square miles together. However, the orchard farms of the Metropolis area, usually called orchard companies, consist of large individual holdings and, as a result, can expand their crops from peaches, the dominant crop. Removal of peach blocks because of age and winter killing has made land available for other crops.

Wheat and cattle have become the chief land uses associated with orcharding here. Villa Ridge growers are giving much attention to truck gardening and small fruit. On some farms they are even more important than peaches. Orchard farms are relatively small in the Villa Ridge area and emphasis has been given to crops which give high yields and high returns per acre. Truck crops meet those requirements. In addition, the Illinois Central Railroad and highways give ready access to markets, another important factor in combining truck farming with orcharding.

The Anna-Cobden area is the most intensely used commercial orchard land in southern Illinois. It is also the oldest and apparently the most prosperous orchard region. Yet the individual growers of the area as a whole combine other cash crops, mainly early vegetables and strawberries, with their apples and peaches. Such crops grow to advantage on the small patches of lower ground which orchardists generally do not use for their peaches and apples.

For various reasons truck farming combines most successfully with orcharding, and this is the combination most highly developed in the Anna-Cobden region (fig. 2). Truck gardens are terminal one-season ventures which can be quickly planted, especially if the orchard prospect looks slim. Much of the same machinery, labor, packing sheds, and marketing facilities can be used for both. There is a definite relationship each year between the amount of

Fig. 2.—Tomatoes in the foreground, peach orchards in the distance. Near Alto Pass.

truck farming and the character of the crop of peaches and apples. When there are good fruit prospects the orchardists do not grow as many vegetables as they do when the prospects are poor. Their first love is orcharding and they are only buying some form of casualty insurance which takes the form of other cash crops.

The high percentage of generally rough to rugged terrain imposes limitations to clean tilled crops such as corn or other vegetables. However, the rugged land is suitable for beef cattle. Dairy cows require constant and daily attention, just as much during the rush of orchard spraying or harvesting times as throughout the year. Most growers prefer more freedom than dairying permits so they can attend professional meetings or take a vacation in Florida—providing they have had a good fruit year.

The New Burnside area, some 25 miles directly east from the Anna-Cobden area, is undergoing some basic and far-reaching changes in its orchard economy, especially with reference to land use associations on individual orchard farms. This region is turning toward livestock, especially beef cattle. Orchard after orchard has been removed and the land put into improved pasture for beef cattle. This is more nearly possible in this region because the orchard farms are large, with a high proportion of steep rough land which can be placed best into permanent pasture. Grower after grower is converting to this combination. Most of the growers favor beef cattle over other types of associated land uses because beef interferes less with the labor requirements of fruit and demands less constant attention. The grower can leave the hired hand in charge of his herd while he attends horticulture meetings or takes off for a few days.

The Centralia-Alma orchard area, some 75 miles north of the other districts, has an entirely different land use association. Here general farming with emphasis on wheat, soy beans, and livestock is commonly combined with orcharding. The nature of the land, the larger size of the farms, and the general discouragement among orchard growers all have influenced the trend toward diversification. Some farmers have abandoned orcharding completely. The land is more gently sloping, even astonishingly level in the orchard areas. This allows more cultivated field crops to be grown without as serious loss of soil from erosion as is true in the Ozark orchard country. Farms are large so that individual farms have room for both orchards and other crops. Finally the growers are in the mood to shift their enterprise toward greater diversification to avoid the disappointing failures they have had in recent years with peaches and apples. Some of the orchardists were only part-time fruit growers in the first place, had only small orchard plantings, and weren't bonafide commercial growers. It has been relatively easy for them to convert to general farming and either give orcharding second place or abandon it altogether.

## Summary

There is a tendency in the orchard economy of southern Illinois to combine other land uses for supplementary cash income. The economic

risks of orcharding make it important to combine other sources of income with deciduous fruit in order to give the grower a firmer financial base. The nature of the land, the size of individual holdings, the availability of land for diversified crops, types of transportation and marketing facilities, all help the farmer decide which type of land use he can combine with his orchards. Yet orchardists in a given region generally choose other land uses that the non-orchardists in the same area stress (see fig. 1). So the orchardists in the Villa Ridge and Anna-Cobden areas emphasize truck farming, small fruits and livestock, their neighbors' major crops. In the New Burnside and Sesser areas, they combine orchards and livestock, the economy of other nearby farmers. Centralia and Metropolis orchardists combine orchards with general farming and livestock, the type of farming that dominates the scene around and about them.

Orcharding is a highly technical, highly skilled, full-time farm operation, and the fact that southern Illinois orchardists divide their time and land is evidence of the precariousness of orcharding in the region. Southern Illinois orchardists have found from bitter experience that they dare not "put all of their eggs into one basket."

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# SOME FACTORS IN THE INDUSTRIAL POTENTIAL OF SOUTHERN ILLINOIS

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The industrial potential of Southern Illinois,[1] like that of most areas, depends upon factors operating not only internally but also externally. Internally such items as available raw materials and water supply are natural factors which influence the potential. In addition there is the human factor. How these function within the area is of course important, but also, external forces, both nearby and distant, may retard or enhance development.

## Internal Factors

*Local raw materials.*—The varied products of its mines, farms, and forests serve as industrial raw materials in Southern Illinois. Manufacturing is commonly developed on a raw material base in instances where goods are perishable, where transportation costs form a considerable part of delivered costs, or where raw materials are more expensive to ship than the finished products. In Southern Illinois the manufacture of dairy products, bakery products, and ice illustrate the first point; wooden boxes and baskets, concrete products, brick and tile illustrate the second, and charcoal the third. These types do not promise great expansion, but they do promise some, and they provide employment for a segment of the population.

*Power.*—Southern Illinois is well supplied with electric energy, but the potential is much greater. Existing facilities are adequate for present electric power requirements and for any normal or anticipated load growth. The three major power generating stations within the area are at Grand Tower on the Mississippi, Hutsonville on the Wabash, and at Muddy near Harrisburg, on the Middle Fork of the Saline River. A fourth is being built at Joppa.

All these stations are located along streams because the water requirement of modern steam plants in many urban centers is greater than the water required for all other uses combined.[2] Water bodies capable of supplying large amounts of condensing water thus are major factors in determining the location of steam plants. In Southern Illinois, therefore, it is to be expected that future plants will be erected along the major streams and their larger tributaries.

The Atomic Energy Commission, through contracts with private companies, is constructing a large power plant at Joppa, Illinois. This plant can favorably affect the industrial potential of the area. Substantial amounts of power from existing sources are now being supplied to

[1] Southern Illinois, as the term is used in this paper, consists of 32 of the 34 southernmost counties of the state of Illinois.

[2] For example, the "....Duquesne Power and Light Plant near Pittsburgh is reported to require six times as much water for condensing purposes as the entire city needs for all purposes." From Erich W. Zimmermann, world resources and industries, New York, 1949, p. 609.

this plant by the T. V. A. and a combine of five private power companies in Southern Illinois, Kentucky, and Missouri. Under a compact with the A. E. C. the private power companies are installing inter-connecting lines, so that power excess to the needs of the project can be distributed back through the member systems. A large surplus of power is expected to be available to business and industry when the plant is completed. It is conceivable that the great concentration of power will serve to attract new industry.

*Water.*—Water is an essential raw material for the nation's industrial plant. Industry cannot survive where water is inadequate in quality or quantity. Southern Illinois, in general, has poor groundwater supplies, but has good surface water sources in the major bordering streams and their tributaries. The southern part of the state is the only portion of central United States which has opportunity to develop industry along both the Ohio and Mississippi rivers.

*Minerals.*—Mineral production in the area was valued at $300,000,000 in 1950. This is greater than that of any western state except California. Minerals are not only abundant but also varied. The industrial potential associated with the mineral resource requires that the various minerals be processed in Southern Illinois factories, rather than exported as raw materials. This will occur as industry matures in the southern part of Illinois and the adjacent portions of bordering states.

*Local market.*—The influence of a local market upon the industrial potential is a function of both population numbers and purchasing power. The absolute size of the area market, in terms of the 1950 population, is 674,000 persons, so distributed that the average density is 49 per square mile.[3] This is too few persons per unit area to create a large enough market to attract new market-oriented industries.

According to estimated data, the effective buying income in 24 of the 32 counties in 1950 was less than $1200, and in 15 of those counties it was less than $1000.[4] When compared to the state average of slightly over $1700, the effective buying power is relatively low. If the area had the same purchasing power in dollars per square mile as the state, it would still be only one-third as effective. Thus the relatively small market in terms of population numbers and distribution is not compensated by large purchasing power.

However, market-oriented industries might be stimulated if the market were expanding. Unfortunately this is not true. The area lost population according to the 1930 and 1950 census reports. From 1900 to 1950 the net increase was 37,000 persons, or 740 per year, a gain which would not require new market-oriented industries, inasmuch as existing facilities could satisfy the slightly increased demand.

*Need for alternative opportunity.*—Severe unemployment in the mining counties, together with under-employment in agriculture, pointed up the need for readjust-

[3] Density of population for the state is 150 per square mile.
[4] Based on data in *Sales Management,* May, 1952.

ment of the economic system. In 1940, there were 58,000 persons, constituting 23 percent of the labor force, on public emergency work or seeking work. The decrease of employment in coal mining and in agriculture, the long time major employers in the productive industries, creates a need for alternative employment opportunity. Manufacturing could provide this employment provided those persons were willing to shift to industrial jobs.

In addition to the large number of unemployed there is potentially available a large proportion of those persons who leave the area. For example, between 1940 and 1950 the area population decreased by 48,607, while the natural increase was 57,453. Thus the area lost about 106,000 persons in the 10-year period. This represents 25,000 to 35,000 potential industrial workers, many of whom prefer to stay in the area.

## Labor as an Uprooting or Retarding Force

There are several aspects of labor which may be considered as negative factors with respect to the industrial potential of the area.

*Organization of labor.*—It seems reasonable to assume that the hesitancy of some companies, seeking new locations, to establish factories in Southern Illinois is due in part to a history of labor strife. The truth is that the area has an unfortunate labor reputation.

Disregarding strikes in the coal industry, which are national rather than local in origin, there are many work stoppages due to jurisdictional disputes. The record shows 34 stoppages within two years on the construction job at Joppa. The opening of a new and unused plant at Herrin, valued at $1,200,000 and intended to employ over 1000 persons, was considerably delayed and seriously jeopardized by lack of understanding between local labor and the new management.

There is nothing inherently wrong with the fact that labor in Southern Illinois is unionized. Labor unions are an established fact in the American economy. Most management officials expect the labor force to be or to become unionized, and some prefer union employees. The disturbing fact, however, is that not only does labor have a poor reputation, but this reputation has spread beyond the borders of the area. As a result it becomes a factor adversely affecting the industrial potential.

*Lack of industrial experience.*—In any industrial consideration it is important to know the nature and degrees of skill in a labor force, for these are related not only to the present economic status of an area, but also to its potential development. The fact that Southern Illinois has depended for so long upon agriculture and mining as major sources of employment means the lack of a large reservoir of labor with industrial experience. A grouping of employed persons into skilled, semiskilled, and unskilled classifications shows a higher proportion of the labor force in the semiskilled and unskilled classes than in either the state or the nation. Furthermore, that labor which is present has had but a short and limited experience. This means added costs and some

loss of productive capacity to new establishments because of time spent to train new employees.

Of great significance also is the spread between factory and mining wages. In the fourth quarter of 1951, of 25 selected major industries in the nation, manufacturing as a whole paid only third highest wages, $1.626 an hour in contrast to $2.236 for bituminous coal mining.[5] Factory workers find it difficult to be satisfied with wages lower than their coal-mining neighbors are getting.

This presents a paradox. An industry which has reached its climax and is on the down grade in terms of employment opportunity is indirectly retarding the initiation and development of a substitute. It is a problem which those persons seeking new jobs and those seeking new factories for their communities must take into serious consideration.

Furthermore, the lower skill of labor in Southern Illinois means that the average wage in the area would be less than the average for the nation, and for industries employing mainly unskilled or semiskilled labor, it would be considerably less. Manufacturing in general does not pay high wages, but it can and does provide steady employment which the coal mining industry does not do. This is a significant point for Southern Illinois labor to consider, a point which apparently has been either overlooked or ignored.

## Labor as an Attracting or Concentrating Force

In contrast to the several negative aspects of labor just mentioned there are several factors which make labor an attracting force for new industry.

*Unemployment.*—The decline in employment in the coal mines and on the farms which began in the 1920's has been continuous. At no time in the past 30 years has the area had a labor shortage, not even during World War II. Instead it has been classed several times as a critical area by the federal government. The long continued lack of sufficient employment opportunity would seem to make labor receptive to an expansion of manufacturing within the area.

*Increased urbanization.*—As is true for the United States as a whole, there has been an increase in the urban population in Southern Illinois. This means a growing concentration of potential workers in urban centers and a supply of labor more readily available to new manufacturing plants. This concentration is favorable in another respect. Urban centers in the heart of the area are so closely spaced that a 50-mile radius from Herrin includes 250,000 persons, or nearly a third of the area's population. Actually the great number of people concentrated in this particular area has been referred to as a dispersed city.

*Commuting readiness.*—Another favorable factor is the readiness with which persons in this so-called dispersed city will commute. A survey of 18 industries in seven towns disclosed that 2400 of the 3400 employees did not live in the town where they worked. Some of them drove more than 40 miles. This willingness to drive rather great distances means that a factory is not

[5] The National City Bank of New York, Arithmetic of steel wage controversy: *Monthly Letter on Economic Conditions, Government Finance,* New York, p. 53, May 1952.

limited to the labor supply of the city in which it locates, but that it can draw workers from adjacent urban centers.

*Management and leadership.*—Most management at present is from the outside. It is brought in with the new establishment. Present management, however, is well trained, particularly that of the larger and more technical industries in which the management personnel was trained in universities, business, and technical schools.

Outstanding leadership has not been demonstrated. No one has been able to unite area leaders into an aggressive and moving force. Neither has leadership been able to overcome local jealousy in favor of area cooperation and benefit. The nearest approach to area organization is Southern Illinois Incorporated, but its work is relatively restricted.

## External Forces

*Effect of St. Louis.*—The industrial development of a given area, as stated earlier, is a function of factors operating not only within but also outside its boundaries. Some of the external forces may be significant but at the same time tenuous when attempts are made to observe them. This, however, is not true with respect to the influence of the St. Louis area. The major portion of the area's transportation network focuses upon St. Louis and thus provides possibilities for a strong attachment.

Evidence of this attachment is the dominance of industry in the eight northwestern counties. Approximately one-third of the establishments in Southern Illinois are in those eight counties. It seems reasonable to forecast that industrial expansion of the St. Louis area will be most favorable to those Southern Illinois counties on its periphery.

*Position and transportation.*—Southern Illinois lies on the southwestern margin of the so-called American Manufacturing Belt. Three major railroads give Southern Illinois excellent access to that area. Favorable transportation time and rates, plus an adequate supply of qualified labor, could be an important positive factor in the industrial potential. Although the labor requirement is not a reality it can be developed under good leadership. This is essential because position in itself is a static factor and must be implemented by human action.

With respect to transportation the advantage seems to lie with Southern Illinois. Most industries now in the area, except for food products, use imported raw materials and sell to a national market. The presence of such industries indicates that Southern Illinois offers a situation and transportation facilities, along with other factors, which permit those industries to meet competition from more highly industrialized areas of eastern United States.

Position has long been recognized as a major factor affecting the location of industries and the development of cities. The excellent central location of Southern Illinois is emphasized with respect to national population distribution. A business man who wished to establish his plant as near as possible to the exact center of the population of the nation would probably locate in Richland County where the 1950 Census

places the center of population.

The change in geographic distribution of population, reflected by the westward shift of the center of population, has notable economic effects. It influences the geographic distribution of income, of the labor force, and of the business population, as well as the flow of new investments and consumer markets. Southern Illinois by its central position stands to gain from these shifts.

*Centrifugal factors in established areas.*—It is also a recognized fact that management in the old established industrial areas is faced with such problems as inadequate supplies of labor, congestion, shifting markets, and competition from new areas. In addition increasing taxes, nuisance regulation laws, and high land values in well developed areas lead to changes in location. As these factors become more pronounced they decrease the values of old locations and enhance those of new ones. Southern Illinois stands to gain as industry makes necessary relocations.

*Functional relationships with the major manufacturing belt.*—Southern Illinois exhibits certain functional relationships with the major manufacturing belt. These may well be strengthened. Functionally it is a source of raw materials consumed outside its border. This relationship may be illustrated by the flow of fluorspar into the major industrial belt, chiefly to the steel industry. The contribution of the area is outstanding inasmuch as it is the major domestic source of fluorspar.

The southern part of the state also serves the function of processing and finishing materials imported from and marketed within the manufacturing belt. This second type of functional relationship may be illustrated by many industries in the area. For example, pig iron and steel from St. Louis and Chicago serve as the basic raw materials for several establishments producing space heaters in several towns. Steel products also serve industries making washing machines and refrigerators. These products serve a national market. Southern Illinois has a good start in this type of industry but can develop more.

*Recent growth in manufacturing.*—Since 1939 the area has expanded its manufacturing structure from 456 to 798 establishments. This growth was accompanied by an increase in the number of employees from 18,000 in 1939 to 30,000 in 1950. Measured on the basis of manufacturing workers per 1000 population the increase amounts to 31 percent. Although this is only about half that of the nation as a whole it is greater than 22 percent for New England and is almost equal to 34 percent for the Middle Atlantic region. This is a significant expansion for an area which is not regarded as being industrialized. Such substantial growth must be regarded as a positive factor in the industrial potential.

It is also important to note the presence of branch plants in the metals, machinery, and transportation industries. These are desirable types in any manufacturing area and Southern Illinois is fortunate in acquiring them. Furthermore, many of them represent branches of major companies, for example, Swift & Co.,

E. L. Bruce Co., International Shoe Co., and Sangamo Electric Co. The factors prompting their selection of Southern Illinois include labor supply, availability of raw materials, and accessibility to markets.

## Summary

Although Southern Illinois lies on the margin of the American Manufacturing Belt it has not shared in the industrial growth of that portion of the nation. Industrial development has been slow even though the area possesses assets common to major manufacturing regions.

Several factors are regarded as having adverse effects upon the industrial potential. These include (a) a large proportion of unskilled and semiskilled workers in the labor force, (b) a poor reputation in labor-management relations, (c) inexperience of local leadership in dealing with factory owners, and (d) lack of coordinated area effort to promote industrial development. In addition, the prosperity associated with the rapid expansion of the coal industry created an atmosphere in which there was little incentive for the development of manufacturing.

In contrast there are several factors favoring industrial growth. The varied products of mines, farms, and forests serve as industrial raw materials. The resource base is varied and capable of sustaining an expanded manufacturing industry. Existing power facilities can be greatly expanded. There is a surplus of labor in the area. Labor commutes readily, which offers flexibility in plant location. Geographical position gives the area a central location with respect to the nation's population, and transportation facilities provide ready access to the Middle West, the industrial Northeast, and the expanding South. Recent acquisition of manufacturing suggests the possibility of further growth.

Natural, economic, and human factors both in and outside the area can contribute to a positive potential for Southern Illinois. Through effective use of the favorable aspects of position, transportation, forests, minerals, power, and the labor force, the prospects for a continued and sound expansion of industry seem favorable. With such development will come a release from an unsatisfactory dependence upon mining and agriculture, the institution of a more balanced economy, more stable employment, and improved living conditions for the people of Southern Illinois.

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# EVAPORATION RECORDS IN ILLINOIS

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The more one studies the subject of evaporation from water surfaces, the more one realizes the complexity of the problem. About ten years ago when I started this study, I asked a professor of agriculture how much water was evaporated or transpired from one of his corn plots. He answered, "Tons and tons of water." "But how much actual water loss is there in a given period?" I asked, and he replied that although he had studied the subject during the whole of his professional life he still did not have an answer to that question.

If the problem is so complex, why do we bother trying to obtain evaporation records? The answer is that no matter how inadequate the data may be, scientifically determined records are of value, and those interested make use of these records.

The average annual rainfall measured at about 175 stations in Illinois is 36.62 inches. This amounts to 99 billion gallons per day. The water that gets into streams and lakes can be measured through stream-gaging installations operated by the U. S. Geological Survey office in Champaign. But, on the average, these gaging stations measure less than 25 percent of the original precipitation.

What happens to the rest of the water? Some of it soaks down into the earth to become part of our groundwater supply. Studies indicate that this is only a very small fraction. Some soaks in and reappears as stream flow. The rest of it is lost through evaporation or more correctly evapo-transpiration. This paper considers only that part of the loss that is evaporated from the water surfaces. This loss is of great importance to industries using surface water sources, to municipalities depending upon surface water reservoirs for their local water supply, and especially to farmers depending upon farm ponds for their water supply. During the last four years there has been great interest shown in irrigation equipment for increasing the yield of certain Midwestern crops. Knowledge of evaporation rates is very important for the irrigator. Such knowledge will help him determine when to irrigate.

## How Are Data Collected?

Nearly all of the published Illinois evaporation records[1] are obtained from "Class A" U. S. Weather Bureau pans. These pans measure 48 inches in diameter and 12 inches deep. They are filled to within 10 inches of the top and water losses are measured with a hook-gage inserted in a still well within the pan. Observations are made once daily, usually at 7:00 A.M. Central Standard Time. An anemometer is located adjacent to the pan and measures the total amount of wind passing over the pan in a day.

Evaporation records are collected at four Class A pan stations and on an experimental basis at three installations in Illinois.

[1] Climatological data, Illinois section, U. S. Weather Bureau.

One of these, located for a 12-month period at Fox Lake near Charleston, made use of sling psychrometers to determine the vapor pressure gradient from the surface upward approximately 20 feet. Using these data with the Meyer formula[2] gave a rough measure of evaporation for that part of the lake. These measurements were discontinued because of lack of personnel at the lake.

In cooperation with the University of Illinois Civil Engineering Department, the Water Survey maintains an evaporation station on the engineering campus at which vapor pressure gradients are measured automatically with instruments known as Foxboro Dewcels. This instrument gives automatically the same type of data obtained by sling psychrometers. The cells give direct dewpoint readings whereas the sling psychrometers gave temperatures from which the dewpoints may be determined by use of Marvin's or other psychrometric tables.

A third experimental station is maintained at Four-Mile Crib in Lake Michigan. At this station a Serdex Microhygrograph located 30 feet above the lake level gives very accurate relative humidity readings, which when combined with air temperature readings may be transferred directly to vapor pressure readings. Attempts have been made to utilize the material thus obtained for measuring evaporation at this location in Lake Michigan. However, it is obvious that a great many such stations would be needed to make an accurate evaluation on evaporation over so large a water area.

[2] Meyer, Adolph F., Evaporation from lakes and reservoirs: Minnesota Resources Commission, 1942.

From the point of continuous operation, the oldest evaporation station in Illinois is operated by the U. S. Weather Bureau at Springfield. The records began in May 1941. The three evaporation pans operated by the Water Survey in cooperation with the Weather Bureau are located near Rockford in northern Illinois, on the engineering campus at Urbana, and at Carbondale in southern Illinois (fig. 1).

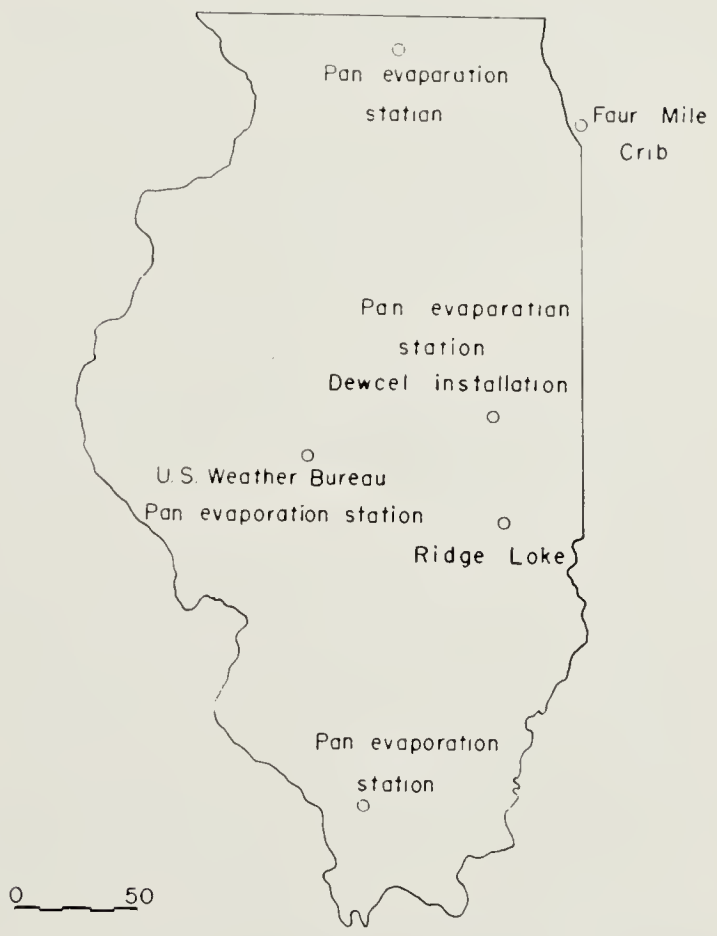


Fig. 1.—Evaporation stations in Illinois.

## What Do the Data Show?

Figure 2 shows the monthly evaporation for four pan evaporation stations, from March 1947 to November 1952. Maximum evaporation generally occurs during July, with the reported exception of 10.40 inches at Springfield in June 1952.

Minimum monthly totals are not significant because pan-type stations cannot be operated properly during

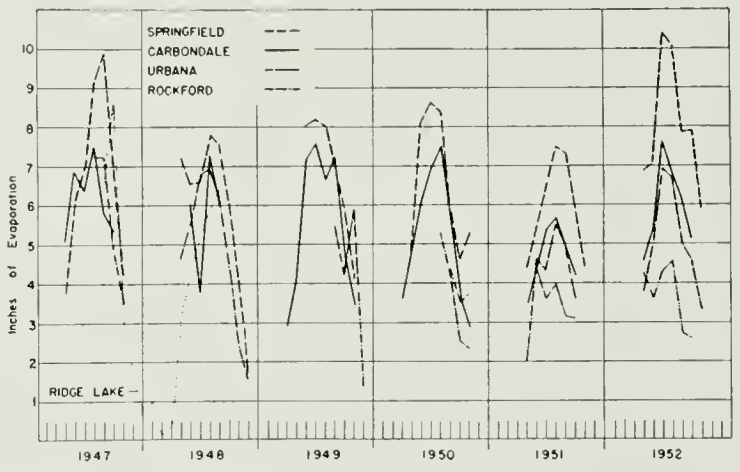


FIG. 2.—Pan evaporation measurements at four Illinois stations.

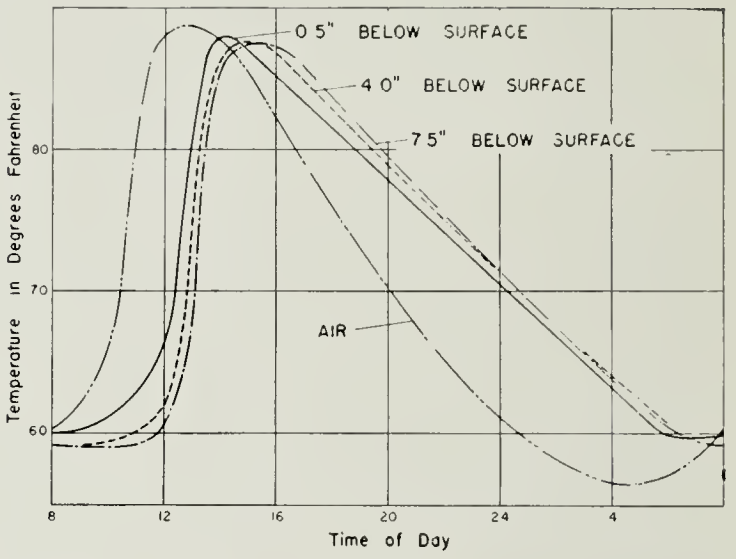


FIG. 3.—Typical temperature gradients in Class A evaporation pan.

the winter months when evaporation is relatively low. The record at Ridge Lake, shown on the left side of the chart, indicates the magnitude of evaporation (or sublimation) to be expected during an Illinois winter.

The average annual evaporation for the 12-year period, 1941 through 1952, at Springfield is 48.59 inches. During the six-year period, 1947 through 1952, Carbondale had an average annual evaporation of 35.46 inches and Urbana 35.05 inches. Rockford, with only a two-year record, has 18.01 inches.

Longer periods of record are necessary before comparisons of evaporation can be made on a latitude basis.

Figure 3 shows typical temperature gradients in a Class A evaporation pan. During the early morning hours the water temperature is uniform vertically. Air temperature changes precede heating and cooling of the pan water by approximately two hours on both the ascending and descending limbs of the chart. The rate of rise or slope in water temperature closely parallels the air temperature elevation and is relatively steep. Pan cooling takes place slowly with a low value appearing before dawn. Insolation causes a rapid rising of the surface temperature. Heating of the deeper water is slower, especially when there is no wind to cause mixing. When the surface water has reached its maximum daily temperature the lower layers continue to take on heat. After the maxima have been reached, cooling throughout the pan is uniform although the bottom water continues to be slightly warmer until morning when the gradient disappears. There was close agreement between shaded and non-shaded sets of thermometers except for the top half-inch layer. This incidentally is a mean relationship rather than any specific case. The effect of sunlight below the top one-half inch was apparently not significant.

## Interpretation of Data

Many authorities have commented on the differences between lake evaporation and evaporation from a pan of water. Pan measurements even when taken near the margin of the lake or from a pan on a raft floating on the lake do not correctly represent the average evaporation for the whole lake surface. Temperature and

wind affect evaporation. Because of these differences actual evaporation from a lake surface is usually less than that measured in an adjacent pan. Horton[3] believed that the most reliable method of determining the evaporation from large lakes was by calculation of data on wind and temperature rather than from evaporation pans. Those that have followed him in study of the Great Lakes have believed that evaporation from large bodies of water such as the Great Lakes cannot be accurately determined. Fortunately for us, the evaporation from the Great Lakes, although a large quantity, is relatively unimportant in the field of water supply.

The formula developed by Horton is very similar to the one mentioned earlier by Meyer. The Meyer formula is:

$$E = C\ (V_w - V_a)\ (1 + W/10)$$

In this formula the evaporation is stated in inches per month and the $V_w$ and $V_a$ are vapor pressures at the surface of the water and 25 feet above the surface. C is an empirical constant dependent upon time, size and character of the water body. W is the wind velocity in miles per hour. Meyer made many comparisons between observed pan evaporation and evaporation computed by means of his formula. Whenever meteorological data, even reasonably suitable for use in the formula were available, he found a satisfactory correlation between observed and computed evaporation.

The most significant recent research on the problem of investigations is reported in Circular No. 229 of the U. S. Geological Survey.[4] This is a study of evaporation at Lake Hefner which was carried on from April 1950 through August 1951, by the Bureau of Reclamation, the U. S. Geological Survey, the Bureau of Ships, the Navy Electronics Laboratory, and the Weather Bureau.

Lake Hefner is a water supply reservoir owned by the city of Oklahoma City. The lake is formed by a long horseshoe-shaped dam located approximately eight miles northwest of the center of the city. The lake and its watershed have several characteristics which make possible a comprehensive study of four basic methods for determining evaporation from water bodies:

1. The water budget method, in which evaporation is determined by the difference between inflow and outflow plus changes in storage.
2. Use of evaporation pans.
3. The thermal energy-budget method, which takes into account all sources of incoming and outgoing thermal energy plus changes in energy storage.
4. The mass-transfer theory, which calls for the measurement of factors affecting removal of water vapor from a water body by the process of turbulent diffusion and transport.

The study group maintained three separate installations around Lake Hefner to provide data for the evaporation pan studies. Regular Weather Bureau Class A pans were installed at each site to indicate areal variations. Water levels in the pans were observed with hook gages, and attempts were made to continue observations through the winter.

The report states that daily pan evaporation at Lake Hefner could be accurately estimated from air tem-

[3] Horton, Robert E., Hydrology of the Great Lakes: Sanitary District of Chicago, 1927.

[4] Water-loss investigation. Lake Hefner studies technical report, vol. 1: U. S. Geol. Survey Circ. 229.

perature, solar radiation, dewpoint, and wind using an energy balance approach. The technique is now being tried experimentally with data collected in Illinois.

From February through April, 1953, the Water Survey built and placed in operation three automatic evaporation-recording machines. These are located adjacent to the evaporation pans located at Rockford, Urbana, and Carbondale. The instruments are modified Stevens weighing-bucket rain gages in which the bucket has been replaced by a flat pan having an area ten times that of the standard collector ring at the top of a standard rain gage. This permits a multiplication factor so that the full travel of the pen across the record chart indicates 1-inch of evaporation. The records from these gages are interesting in that they show when evaporation is greatest. This type of instrument should prove particularly beneficial when the temperature is below freezing. It should also prove of value in particular studies where daily measurements of water loss are not sufficient for correlation purposes and an hourly record would be more desirable.

It is only natural to expect that the standard pan measurements will be superseded by a formula which will require only a knowledge of wind and temperature in the area being studied. However, until such short-cuts are available we shall continue to collect water loss data by all practicable methods including the Class A pan.

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# METHODOLOGY OF RADAR-RAINFALL QUANTITATIVE STUDIES

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This is a summary of the methods used in solving an existing problem of meteorology and climatology. The problem concerns efforts to measure more accurately areal rainfall amounts resulting from high variability type precipitation. For many areas of the world subject to the thunderstorm type of rainfall, our present climatological data concerning rainfall amounts cannot give a true areal presentation of the occurrence nor the quantity.

Ordinary rain gage networks cannot provide detailed information on the distribution of thunderstorm rainfall, and the cost of establishing rain gage networks for this purpose over large areas would be prohibitive. A few scientific groups, associated with related state and federal government agencies, after World War II began to investigate the ability of radar to provide the detailed information on storm rainfall.

World War II introduced radar, a radio-wave detection apparatus, which has since been adapted to detect precipitation. Preliminary studies have concerned the use of radar for determining the mechanism of rainfall. However, more recent studies using specialized analytical methods and radar modifications are proving that radar can also be used for quantitative measurements of rainfall. To this end such research in Illinois has shown that results from one radar set are at least as accurate as data obtained from a network having one gage to 200 square miles, and often as accurate as one gage to 50 square miles. Since December 1950, Illinois has had one gage for every 230 square miles.

The Illinois State Water Survey, to compare radar and rain gages, has used during the past five years three small watersheds in Illinois for research studies. During 1951 the Goose Creek watershed lying 20 miles west of Champaign was used as a pilot study area. It totaled 49 square miles, and had 33 recording rain gages resulting in a ratio of one gage per 1.5 square miles all located in a radial geometric pattern (fig. 1). Detailed comparative studies of rain gage and radar results were made in the following manner.

Radar search was run 24 hours daily during the summer months on 120 mile range viewed on a Plan-Position Indicator scope, which is a presentation resembling a map view of the studied area with the radar set at the center. When rainfall echoes appeared, 35 mm photos, one frame per minute, were taken of the PPI scope for use in later analysis.

Immediately, the question arises concerning how radar evaluates rainfall amounts in the rain echoes. A radar beam is basically a radio wave signal which is sent out from the radar set, and if reflected back by rain or large metallic objects creates a 'blip' on the scope, correct for distance and azimuth from the radar set. When the receiver sensitivity is

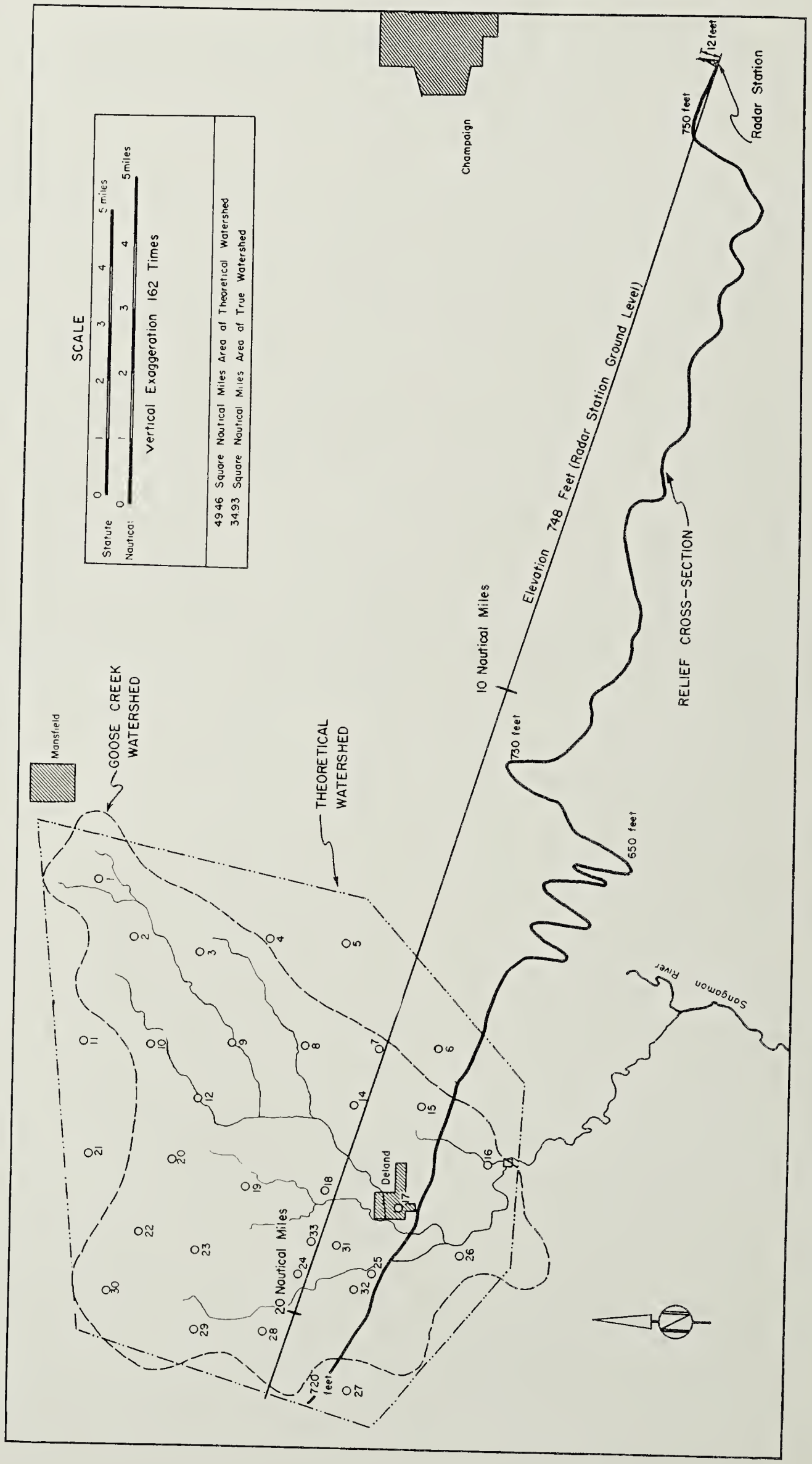



FIG. 1.—Map of radar station and rain gage location in respect to Goose Creek watershed.

decreased, it takes bigger targets to get an echo on the radar scope, and for rainfall these increased targets must be higher rainfall rates and/or larger raindrops. Consequently, by decreasing the receiver sensitivity in measured 'steps' rain echoes can be described and analyzed quantitatively (fig. 2). These electronic 'step' values are related to known rainfall rates. A picture frame is taken of each step every minute including the total number of steps necessary to eliminate even the most intense rain-

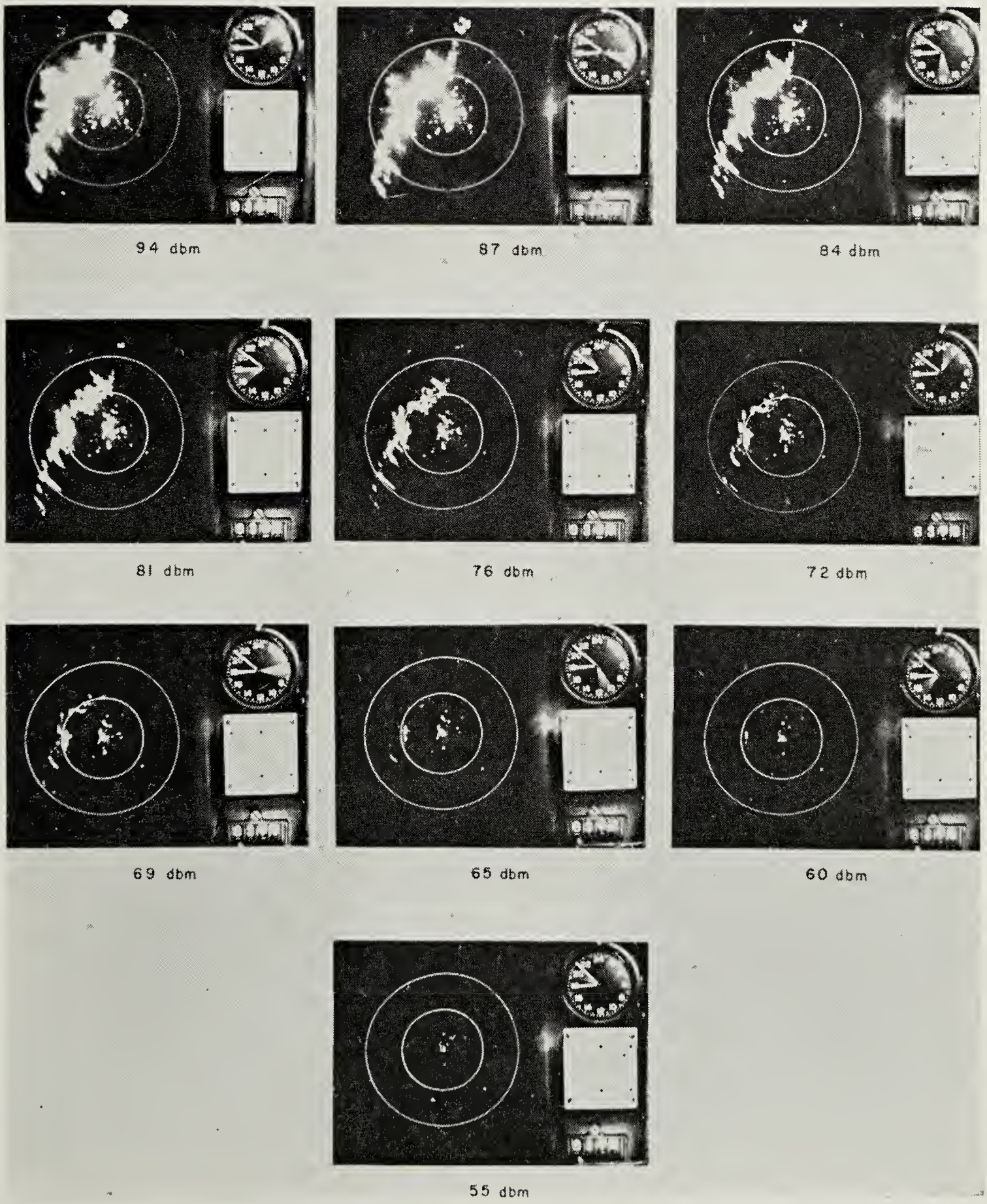


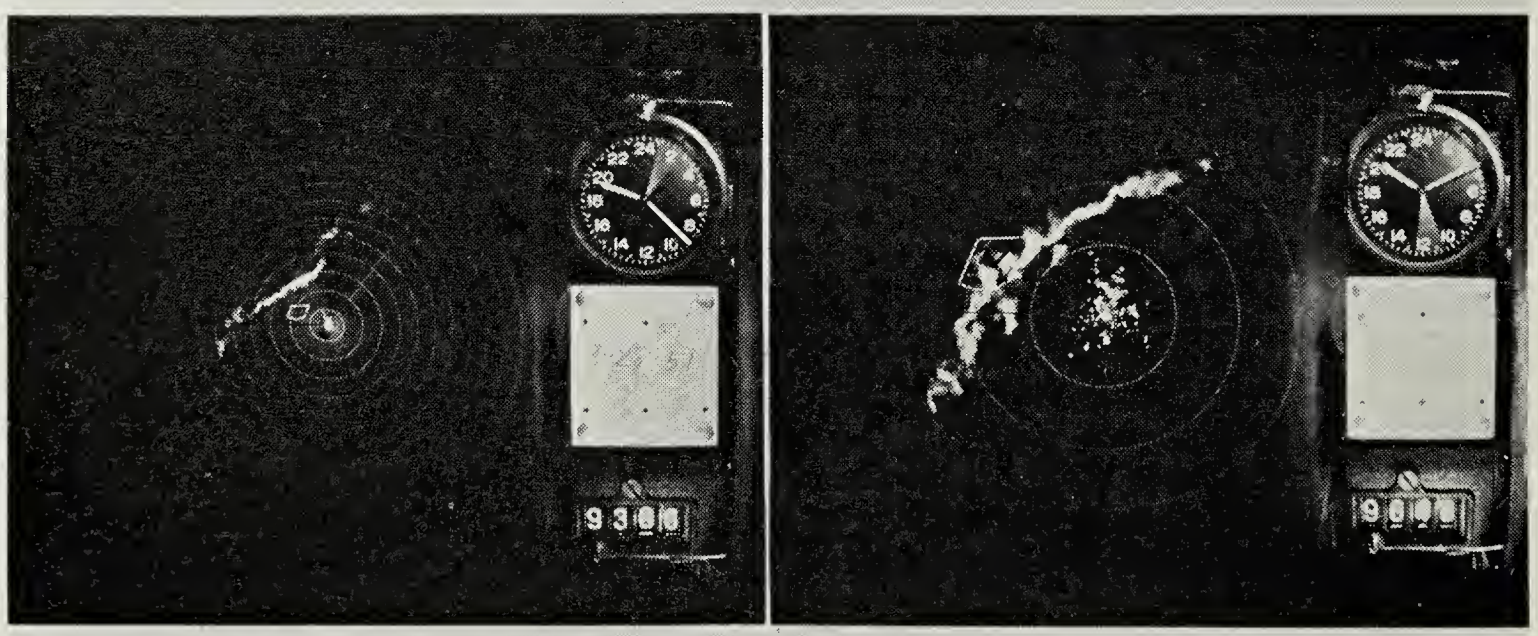

FIG. 2.—Isoecho contonrs obtained from ten steps of redнction with antomatic sensitivity control. Smaller echoes represent areas of heavier rainfall rates.

fall core in the echo. From the film of each storm, each individual frame must be projected upon a large base map of the watershed, and isoecho (contour) lines traced off for each series of 'steps'. For each storm there are several hundred frames, and the aforementioned tracing process, isoecho map planimetering, plus final statistical calculation becomes a time-consuming process.

## The Storm of September 26, 1951

Over a period of 40 minutes during the evening of September 26, 1951, a long, narrow cold front squall line with several individual thunderstorm cells moved across the Goose Creek watershed from the northwest (fig. 3). Excellent rain gage and radar data were collected with 0.79 inches of rainfall representing the maximum rain gage catch. The radar calculations indicated 9 percent less total rainfall than the total rain gage accumulation. Analysis proved that for this storm radar was as accurate as one rain gage per 22 square miles (11).

ISOHYETAL PATTERN ISOECHO PATTERN



RADAR SCOPE PICTURE AT 1922:05 WITH 10 MILE RANGE MARKERS. RADAR SCOPE PICTURE AT 2010:30 WITH 10 MILE RANGE MARKERS.

COMPARATIVE RAINFALL MAPS AND SCOPE PICTURES
RAINFALL IN INCHES PER HOUR FOR 26 SEPTEMBER, 1951

Fig. 3.

Comparison of the isoecho and isohyetal map patterns (fig. 3), which were mapped at similar time intervals while the storm was over the watershed, indicates two relevant factors common to most comparisons of radar-rain gage patterns. The first is that the leading edges of most patterns, the eastern side, are the best criteria for comparison. The second concerns the lack of exact correspondence between patterns and rainfall rates, most of which can be attributed to present limitations of radar's utility in rainfall detection.

## Limitations of Radar-Rainfall Detection

Since radar signals are straight line-of-sight waves unable to remain at the same elevation owing to the earth's curvature, only high-level rainfall patterns are viewable at distances much beyond 80 miles from the radar. Consequently, rain from lower-level clouds will be missed at the longer ranges. Furthermore, it must be realized that the signal plane intersecting falling rain at a certain distance aloft is related to distance, and consequently actual rainfall patterns on the ground are often different because of wind drift, change in drop size, and evaporation occurring below the radar observation level.

Radar reflection is a direct result of size of raindrop, and the present lack of detailed knowledge on raindrops limits precise evaluation of rainfall rates. Stabilization and standardization of present radar equipment is lacking and must be accomplished before accurate comparable data can be expected. Much present-day equipment tends to be unavoidably variable in electronic accuracy.

Possibly the greatest limitation in the use of radar in measuring rainfall quantitatively is the aforementioned time-consuming procedure of analysis. However, work is being done on an instrument which will do the complete analysis and computation process electronically. With so many limitations the utility of radar may appear questionable, but it must be remembered that the present status of this research represents only the initial phases of work. Many of the other limitations have foreseeable solutions, and will be eliminated as research moves foreward. The outlook for nsing radar in quantitative rainfall study is very promising.

## Geographic Qualities and Summary

In meteorology and hydrology, and therefore in some aspects of geography, many problems require determination of the total or average amount of rainfall in a given area. The data available for such determinations have usually been the collection of rainfall in rain gages spaced rather sparsely over the area for which estimates have been desired. The question arises then as to how well the average precipitation in an area is measured by gages. This problem is especially acute in measuring precipitation for the thunderstorm type of rainfall.

The pioneer work done on radar usage for investigating isolated precipitation seems to be proving significant in obtaining the data desired. This significance directly and indirectly relates to many research and applied phases of geography. In

respect to agricultural groups, large corporations and government agencies interested in water resources, this radar-rainfall areal analysis and measurement find relevance. The study of areal variability of rainfall definitely has a significance from place to place on the earth's surface and a resulting geographic usefulness.

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# GEOLOGY

## PROBLEM OF INVERTED ZONES OF METAMORPHISM IN WESTERN NEW HAMPSHIRE

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The general geology of western New Hampshire and neighboring areas (fig. 1) will first be described. Though this description is brief and somewhat incomplete, it will be found adequate for an understanding of the present paper. The stratigraphic details are presented in table 1.

East of the Northey Hill thrust (shown extending N-S across the entire map) is a belt of mantled gneissic domes. These Oliverian domes lie along the crest of a major structural feature, the Bronson Hill anticline. Each dome consists of a central core of feldspar gneiss surrounded or mantled by metamorphosed stratified rocks of Ordovician (?) age or younger. In general the gneissic cores are both conformable and concordant with bedding and schistosity of the adjacent metamorphic rocks (schist, quartzite, and amphibolite), and dips are radially outward.

East of the Bronson Hill anticline are mostly schist and gneiss of Devonian age (Littleton formation). Two large masses of feldspathic gneiss known as the Bethlehem gneiss and Kinsman quartz monzonite are shown on the map. These masses are conformable and in general are concordant with the adjacent rocks. They are considered (Chapman, 1952) to represent highly recrystallized and metasomatized portions of the pelitic Littleton formation.

Between the Northey Hill thrust and the Ammonoosuc thrust (to the west) are highly folded metamorphic rocks derived from volcanics and pelitic and sandy material. Structurally this unit is the southern extension of the Salmon Hole Brook syncline (Billings, 1937), but it is interrupted in a few places by small domical features. The most conspicuous of these is the Lebanon dome (5)* with its core of somewhat foliated granite. In some respects the Lebanon dome resembles the Oliverian domes to the east.

Domal structures are conspicuous features in the middle Ordovician and older rocks of eastern Vermont. At the north of the map is the Strafford dome (3) and immediately south of this is the Pomfret dome (4). In the central part is the Chester dome (8), a large and highly complicated structure, with an apparent core of gneiss. To the south are two smaller domes. The one on the west, showing a gneissic core, is the Sadawga dome (11); the eastern one is the Gilford dome (12).

As can be seen from figure 2, the severity of metamorphism in New Hampshire increases from west to

* Numbers and letters in parenthesis refer to points and quadrangles shown in figure 1.

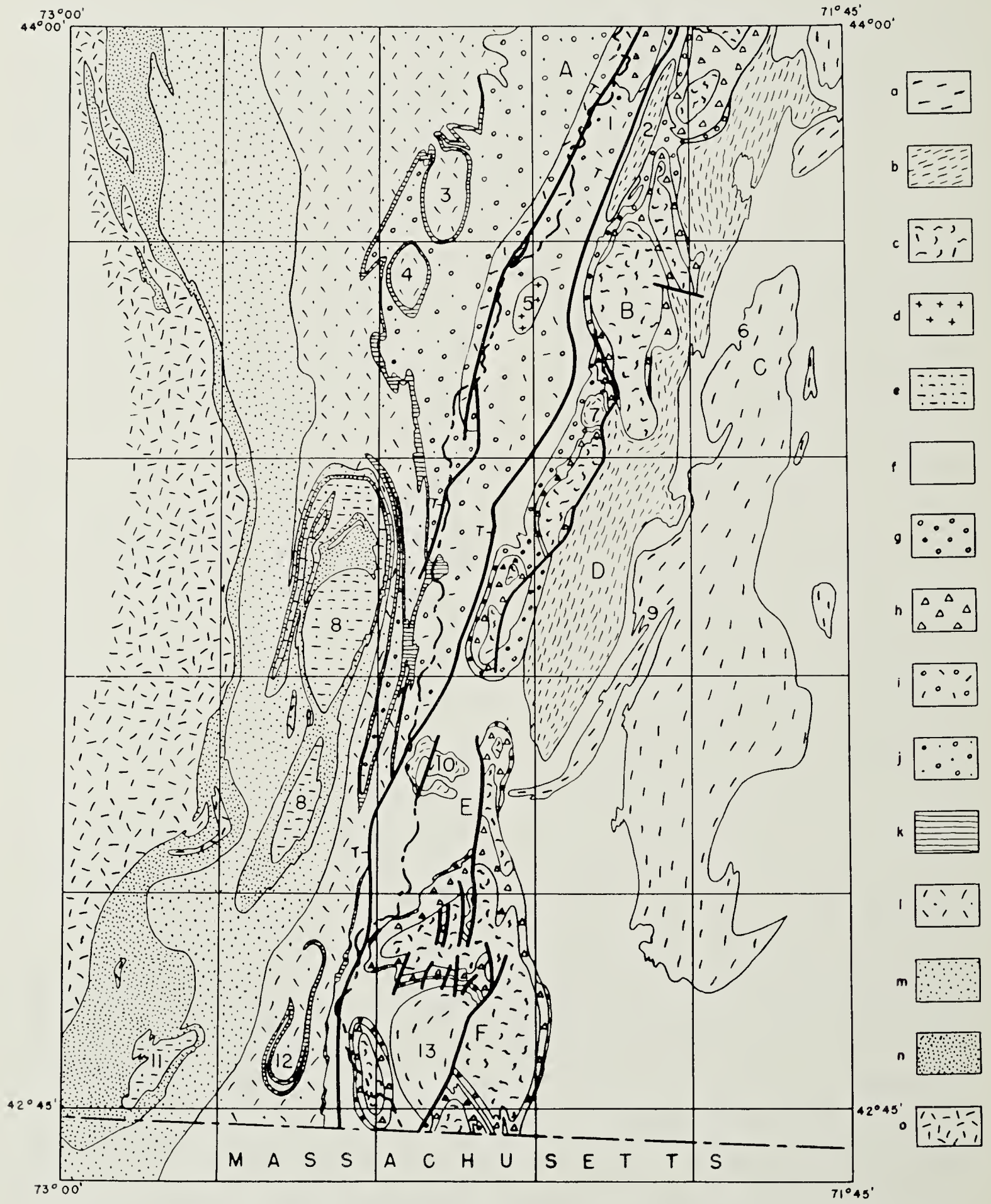


FIG. 1.—Geologic map of southwestern New Hampshire and southeastern Vermont (simplified after Billings, Rodgers, and Thompson).

Key to symbols: a—Kinsman quartz monzonite, b—Bethlehem gneiss, c—Oliverian gneiss, d—Lebanon granite, e—gneiss of Vermont domes, f—Lower Devonian (Littleton formation), g—Silurian (Fitch and Clough formations), h—Upper Ordovician? (Partridge, Ammonoosuc volcanics, and Albee formations), i—Middle or Upper Ordovician? (Orfordville formation), j—Middle Ordovician (Gile Mountain formation), k—Middle Ordovician (Standing Pond volcanics), l—Middle Ordovician (Shaw Mountain, Northfield, and Waits River formations), m—Cambrian or Ordovician (Pinney Hollow, Ottauquechee, Stowe, Moretown, and Cram Hill formations), n—Cambrian or Ordovician (Tyson and Hoosac formations), o—Pre-Cambrian (Green Mountain basement complex).

TABLE 1.—STRATIGRAPHIC DATA FOR WESTERN NEW HAMPSHIRE

| Age | Formation | Original composition | Approximate thickness (In feet) |
|---|---|---|---|
| Lower Devonian | LITTLETON | Shales and shaly sands | 10,000 |
| Middle Silurian | FITCH | Calcium and magnesium limes shale, and sands | 0-700 |
| Middle or Lower Silurian | CLOUGH | Sands and congolomerate | 0-1000 |
| ——UNCONFORMITY—— | | | |
| Upper Ordovician ? | PARTRIDGE | Shale and shaly sands | 0-2000 |
| | AMMONOOSUC VOLCANICS | Rhyolitic to basaltic | 2000 |
| | ALBEE | Sands and shaly sands | 5000 |
| Middle Ordovician ? | ORFORDVILLE | Shales, shaly sands, volcanics | 5000 |

east. In the western part of the state the rocks lie within the biotite zone. To the east the garnet isograd is passed and the rocks may carry garnet. Further east, as we approach the Oliverian domes, staurolite characterizes the next higher grade; and still further east, on the eastern flank of the Bronson Hill anticline (the Oliverian domes), the rocks are in the sillimanite zone.

It has been shown (Chapman, 1952) that in the Sunapee quadrangle (D) the rocks above the sillimanite isograd may be subdivided into three zones: (1) a lower grade zone in which sillimanite and muscovite are stable; (2) an intermediate zone in which microcline develops at the expense of muscovite; and (3) a higher zone in which microcline and garnet develop at the expense of biotite.

Table 2 shows the relation between the zones described above and the facies of the metamorphic rocks in the area. For convenience the zones as shown in the table will be used throughout the rest of this paper.

Relating these metamorphic zones to geologic features we find that the grade of metamorphism increases eastwardly across the Salmon Hole Brook syncline to the Northey Hill thrust. To the east of the thrust is the Bronson Hill anticline with the Oliverian domes almost entirely within the staurolite zone. East of

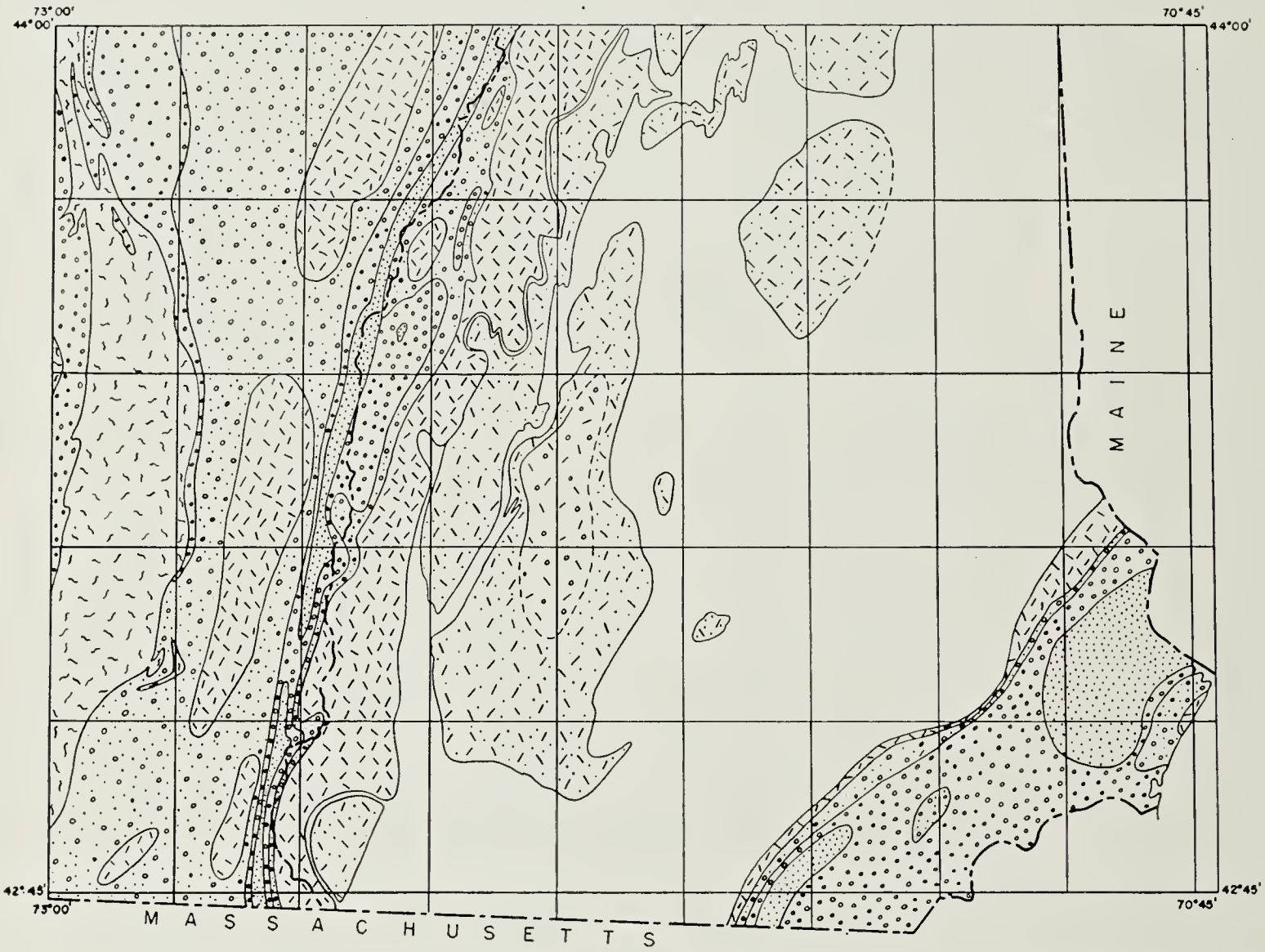


FIG. 2.—Metamorphic zones of southern New Hampshire and southeastern Vermont (modified after Billings, Rodgers, and Thompson).

Key to patterns: vermicular—retrograde zone, stippled—chlorite zone, circles—biotite zone, dots and circles—garnet zone, dashed—staurolite zone, blank—sillimanite zone, dots and dashes—muscovite → microcline zone, circles and dashes—biotite → microcline zone.

the domes is the sillimanite isograd which follows closely the western boundary of the Bethlehem gneiss. This gneiss is considered (Chapman, 1952) to represent a slightly higher grade of metamorphism than the sillimanite rocks to the west. At the east boundary of the Bethlehem gneiss, sillimanite schist and gneiss of the Littleton formation again appear and are of the same metamorphic grade as the sillimanite rocks along the west boundary of the gneiss. In fact we may trace the

TABLE 2.—ZONE AND FACIES CORRELATION FOR WESTERN NEW HAMPSHIRE

| Zones | Chlorite | Biotite | Garnet | Staurolite | Sillimanite | Muscovite→ microcline | Biotite→ microcline |
|---|---|---|---|---|---|---|---|
| Sub-facies | chlorite-muscovite | chlorite-biotite | chloritoid almandine | staurolite-kyanite | sillimanite-almandine | | |
| Facies | greenschist | | epidote-amphibolite | amphibolite | | | Granulite |

sillimanite rocks all the way around the south end of the Bethlehem gneiss, more or less isolating this higher grade feldspathic gneiss on the map. Upon passing eastward into the Kinsman quartz monzonite (a gneiss closely resembling the Bethlehem gneiss), the grade again rises to that comparable with the Bethlehem gneiss and then finally to a slightly higher grade in the eastern part of the area.

Considering the relations from a three-dimensional viewpoint, it appears that west of the Oliverian domes (Bronson Hill anticline) the metamorphic zones are superimposed so that the lower grade zones overlie successively higher grade zones, and the zonal boundaries or isograds are inclined to the west. To the east of the Oliverian domes it can be shown in the field that the isograds dip eastwardly at moderate angles, giving a reverse relationship in zone superposition. Evidence for and the significance of this zonal arrangement will now be considered.

At many places in the field the Bethlehem gneiss rests upon rocks of lower grade metamorphism. Particularly striking examples have been described in the Mascoma quadrangle (B) (Chapman, 1939), Bellows Falls quadrangle (E) (Kruger, 1946), and the Sunapee quadrangle (D) (Chapman, 1952). In figure 1 the large masses of Bethlehem gneiss near the towns of Grantham (7) and Bellows Falls (10) are westward extensions of the main mass. They are basin-like structures and overlie slightly lower grade metamorphic rocks. Not only are these structural relations clearly established by geological field studies, but seismological studies (Kruger and Linehan, 1941) show that these basin-like masses have floors at the same depths, as extrapolated from geologic data, and that the underlying rocks may be correlated with a lower metamorphic grade. It seems very reasonable to assume, therefore, that these two masses of Bethlehem gneiss form westward projections from the main body, which extended completely over the Bronson Hill anticline.

Further north in the Mt. Cube quadrangle (A) is an elongate mass of Bethlehem gneiss known as the Indian Pond pluton (2) (Hadley, 1942). This mass may also represent a remnant of a once continuous layer of Bethlehem gneiss. The same is probably true of the Green Mountain pluton of the Moosilauke quadrangle (Billings, 1937) further north.

It seems quite clear that, in the region mapped by the writer, the Bethlehem gneiss represents a zone of higher-grade metamorphism which overlies rocks of lower grade. The zonal boundary which will be referred to as the muscovite→microcline isograd is believed, therefore, to incline eastward at a low to moderate angle.

If we investigate the eastern boundary of the Bethlehem gneiss, we find that it also dips eastward at a moderate angle, but here the metamorphic zone structurally above is of a lower grade (sillimanite zone). The attitude of this dipping contact at numerous localities has been considered in more detail by Fowler-Lunn and Kingsley (1937), Chapman (1939 and 1952), and Heald (1950).

It appears then that the Bethlehem gneiss is a tabular mass, belonging to the muscovite → microcline zone,

for the most part underlain and overlain by the sillimanite zone.

In the Cardigan quadrangle (C) (Fowler-Lunn and Kingsley, 1937) the Kinsman quartz monzonite is structurally above rocks of the sillimanite zone. This relationship is conspicuous on Mt. Cardigan (6) where the contact dips east at a low angle. The same relation holds for the Sunapee quadrangle (D) except that the contact is steeper. One striking feature should be noted here, however. The lower boundary of the Kinsman quartz monzonite (which is also the approximate boundary of the sillimanite and muscovite → microcline zones) is very irregular. On Sunapee Mountain (9) the two rock types show interfingering relations so that in places the sillimanite rocks are structurally above and in places structurally below rocks of the muscovite → microcline zone. On the grand scale, however, the muscovite → microcline zone (Kinsman quartz monzonite) rests on the sillimanite zone, and the zonal boundary between the two grades inclines at a high angle to the east.

In the extreme eastern part of the Sunapee quadrangle (D) (Chapman, 1952), Kinsman quartz monzonite of the muscovite → microcline zone passes eastwardly into Kinsman quartz monzonite of the biotite → microcline zone. This highest isograd is only approximately located and information as to its attitude is lacking. It seems likely, however, that the dip of the isograd is very steep.

One further striking example of the muscovite → microcline zone overlying the sillimanite zone is seen in the Keene quadrangle (F) (Moore, 1949) where a mass of Kinsman quartz monzonite (13), about 10 miles long, occupies the center of a large structural basin surrounded by several Oliverian domes.

## Theoretical Considerations

The long prevailing idea that regional metamorphism is due to increased temperature and pressure is associated with the concept that grade of metamorphism is in part controlled by depth. Such a line of thinking has led to the idea that in the normal case the grade of metamorphism should increase with depth, and that there is such a thing as a "normal sequence" of metamorphic zones in which a lower grade zone overlies a higher grade zone. Tilley (1925) concluded that the metamorphic zones along the Highland Border in Scotland were not in this "normal" order as Barrow (1912) formerly believed, but that they formed an "inverted sequence." Tilley visualized the zones as being locally overturned mechanically subsequent to the establishment of a "normal sequence." Read (1940), however, pictures the formation of "inverted" sequences not so fortuitously. In fact he raises the question as to whether there is necessarily any normal relationship between metamorphic grade and depth. To him there is little justification for establishing a normal and an inverted sequence. The writer feels, however, that the terms *normal* and *inverted* are helpful when used purely arbitrarily to denote orders of zonal arrangement, rather than to express a standard relation in contrast to an irregular one. In this paper, therefore, the "normal" arrangement of zones is merely one in which the lower grades of metamorphism overlie higher grades, and the

"inverted" arrangement expresses the reverse order. Thus no genetic significance is attached to these terms.

The value of determining the attitude of metamorphic zones lies in the light which zonal arrangement throws on the causes of metamorphism.

In the area of western New Hampshire already described, it appears that inverted zonal arrangements are about as common as normal sequences. The Bethlehem gneiss and easterly bordering schists show a normal order, but the same gneiss and the westerly bordering rocks present a clear case of inverted order. The Kinsman quartz monzonite gneiss and the westerly bordering rocks are arranged on a grand scale in the reverse order. In detail, however, several alternations of rock types are noted on Sunapee Mountain (9), with corresponding alternations in the orders of zoning.

West of the Bethlehem gneiss, in the area of the Oliverian domes, it has not been possible to establish with certainty the type of zonal superposition.

If we look further west in New Hampshire and even into western Vermont, we find a very close correlation on a broad scale between the larger structural features and the distribution of metamorphic zones on the map. Thompson (Billings, Rodgers, and Thompson, 1952, p. 15) has remarked on the association of high grade rocks (staurolite zone) and certain domes in eastern Vermont. From figures 1 and 2 it is clear that the rocks of the Strafford-Pomfret dome (3, 4) and the Chester (8), Sadawga (11), and Gilford (12) domes are surrounded by a lower grade of metamorphism. In New Hampshire, furthermore, the Lebanon dome (5) and the structural high (1) in the center of the Mt. Cube quadrangle are also surrounded by a lower grade of metamorphism.

This coincidence of structural and metamorphic highs might be taken to indicate a normal arrangement of metamorphic zones. Where upward displacement of the rock formations is revealed by the development of domes and anticlines, exposing cores of stratigraphically lower formations, isograds have also been uparched, so that more deeply buried metamorphic zones (higher grade) now appear at the surface completely surrounded by more shallow zones of lower grade.

An alternative explanation is that the association of metamorphic and structural highs is not due entirely to domal uplift. It seems quite logical to the writer that the cause of doming may be found in the severity of metamorphism. Metamorphism may have proceeded to such a stage that mobilization of more deeply buried rocks caused doming. Again one may, if one prefers, attribute the rise in metamorphic intensity to domal cores of magma. In any event, it seems clear that the driving force of metamorphism in this area has come from more or less directly below and not from above or laterally.

From his work in the Sunapee quadrangle (D) (Chapman, 1952), the writer concluded that the Kinsman quartz monzonite and Bethlehem gneiss were originally pelitic rocks of the Littleton formation, and not too different in compositional

make-up from the rocks of that formation shown separately on the map (fig. 1). Through metamorphic and metasomatic changes, the pelitic sediments were converted to biotite-quartz-feldspar gneiss characterized by large porphyroblasts of potash feldspar. There is little evidence that the rocks of the Littleton formation originally contained abundant feldspar; and it is believed, therefore, that some sodium and perhaps some potassium were added to form sodic plagioclase and microcline, although most of the potash feldspar must have formed at the expense of potential muscovite.

It is generally agreed by the numerous investigators who have studied the Bethlehem gneiss in detail that it is a tabular body which on the grand scale is concordant as well as conformable with the adjacent non-feldspathic schist and gneiss. The same relations are believed to hold generally for the Kinsman quartz monzonite. If these bodies of feldspar gneiss are the result of recrystallization and metasomatism, it appears that they developed in general along certain beds and preferred layers or zones so as to form an intertonguing relation with non-feldspathic rocks, and that this uneven advance of metamorphism (and metasomatism) has resulted in isograds or zone boundaries which are also irregular and complex. It is to be expected that, in view of this irregularity, pockets of rocks of lower grade metamorphism may be isolated by rocks of higher grade metamorphism and vice versa. Inclusion-like masses of schist in the feldspar gneiss and lens-like bodies of feldspar gneiss in schist may represent such isolated pockets.

In an attempt to restore the isograds in western New Hampshire, the writer has arrived at the following picture. On the broad regional scale the metamorphic zones are arranged in a normal order and incline in a westerly direction. In detail, however, the isograds are highly irregular; and from surface mapping one is impressed by the rapid and frequent changes from normal to inverted order of zones. From figure 3 it is seen that this alternating arrangement is a logical consequence of the tongue-like projections of higher grade zones into lower and vice versa. The metamorphic potential in western New Hampshire apparently decreased in an upward and westerly direction. It seems that the driving force of metamorphism must have had a deep seated origin below the central part of the state.

The irregularity of metamorphic advance is believed to be controlled in large part by rock composition and structure. It is possible, however, that metamorphic zones have been somewhat deformed by the orogeny to the extent that certain irregularities may be due to flowage, folding, and faulting. It seems reasonable that in the higher grades of metamorphism, where metasomatism is more severe, the isograds would be more irregular, whereas in the lower grades, where large scale movement of material is less likely or movement is more diffuse and quantitatively less important, zones of metamorphism would be separated by smoother isograds.

If this line of reasoning is applied to the southeastern part of New Hampshire (fig. 2), one might assume that the decrease in metamorphic potential toward the coast

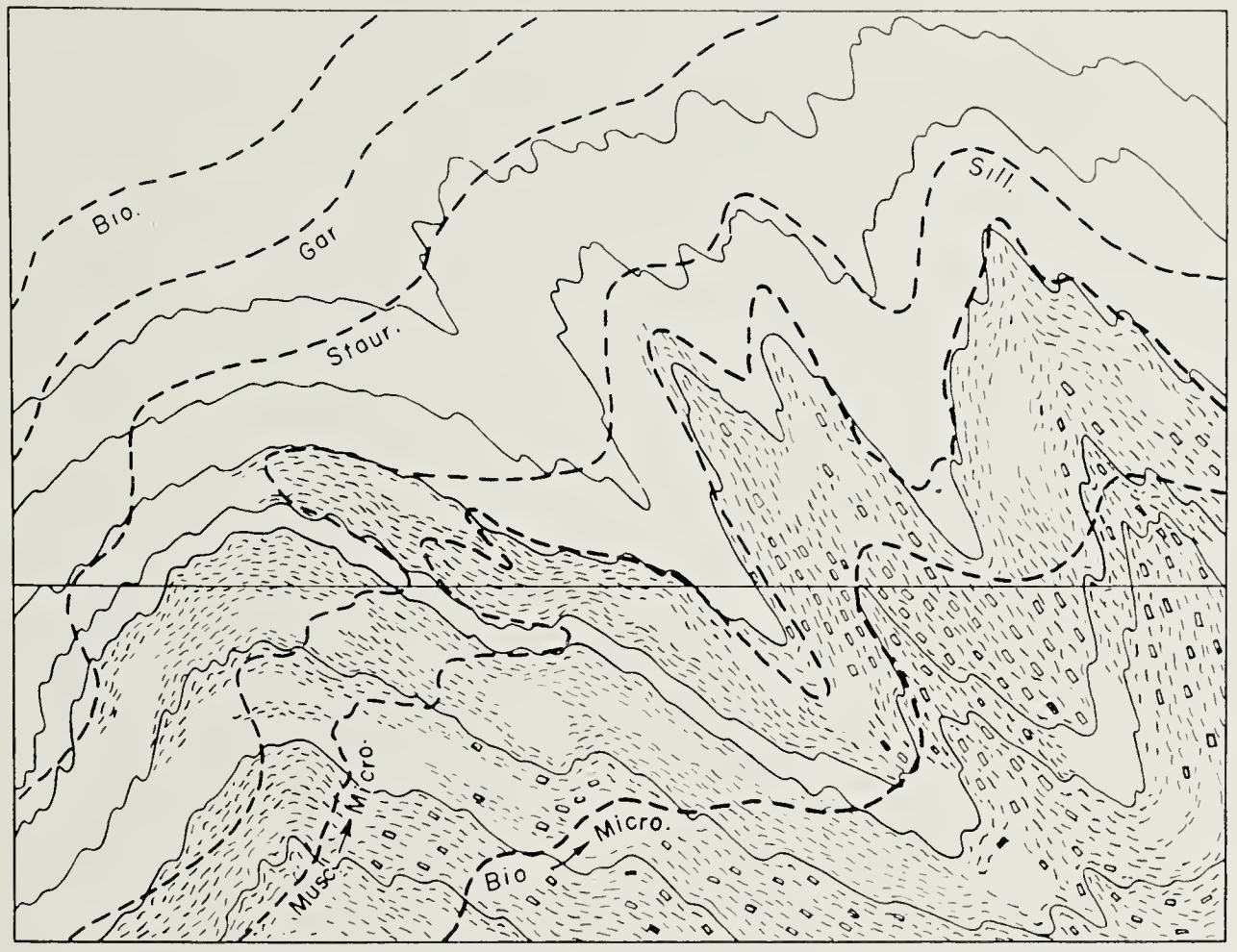


FIG. 3.—Schematic cross section of western New Hampshire, showing folded structure with an Oliverian dome on the west (*left*) and the Kinsman quartz monzonite gneiss on the east (*right*). Horizontal line—present land surface; heavy dashed lines—isograds; dashed pattern—quartzo-feldspathic gneiss.

(southeasterly) is a consequence of the arch of metamorphic zones which culminates in the central part of the state. This gigantic metamorphic anticline, or more properly anticlinorium, may owe part of its arching directly to orogenic movement and isostatic uplift in the central belt.

In conclusion, it appears that the advance of the metamorphic wave into the rocks of western New Hampshire has not come from directly below but obliquely from some depth beneath the central part of the state.

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# GEOLOGICAL OBSERVATIONS OF CAPTAIN JOHN SMITH IN 1607-1614

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The fabulous and famous John Smith (1580-1631), always referred to as "Captain John Smith," has been more highly regarded for veracity in this century than he was in the preceding one (McIlwaine, 1947). There is now a tendency, on the basis of confirmation from various sources, to take Smith's autobiography (1630), including the story of Pocahontas, quite seriously. His claim to notice in any history of early American natural history (Goode, 1901, p. 371) or of early American geology rests upon his observations on natural history, mineral resources, and physical features recorded in his several books on Virginia and New England which appeared between 1608 and 1631.[1]

It is hard to realize that the Captain John Smith who was the actual and later the titular leader of the Jamestown colonists was in 1607 a man not yet 27. All his incredible adventures as seaman, soldier, shipwrecked mariner, ambassador, Turkish slave, escapee and traveler in Europe, Turkey, North Africa, and Ireland took place between his thirteenth and twenty-fourth birthdays! When he sailed to Virginia with the settlers it was as one of those who had invested in the project and not as a hired member of the party.

From Smith's voluminous writings and his compilations of the writings of others, especially of his old companions in arms, Phettiplace and Todkill, it appears that Smith himself early became skeptical about finding precious metals or a route to the Indies. One gets the impression that he felt from the first that the real future of Virginia lay in colonization and the development of trade. His attention to soil types confirms his interest in agricultural resources. One almost feels that he realized that the type of settlement of the Spaniards, based on extraction of precious metals and its necessary exploitation of the natives, was not to be desired for the English. Indeed, he is honest enough on one occasion to write that the hope of finding gold was used only to secure backing for his voyage to New England. He was obviously thoroughly familiar with Thomas Hariot's (1588; White, 1952) sane and sensible report of Virginia (actually North Carolina) resources and appears to have relied more on it than on the rosy compilations of Eden (1555) on Spanish gold.

## Smith's Map and Description

Smith's first book, *A True Relation . . .*, published in 1608 (the first printing does not have Smith's name as author) contains little on obser-

[1] I am much more sympathetic to the viewpoint of Arber (1910) and McIlwaine (1947) about the veracity of Smith than to the carpingly critical view of Brown (1891). I have come to this attitude on topographic and geologic grounds—his geologic and physiographic observations "stand up." To professional historians must be left the assessment of the Smith-Newport administrative antagonism, but there can be no doubt that Smith was right and Newport wrong on the precious metal resources.

vations of natural history and nothing that is not in later, more full accounts. The principal source of information on the Virginia seen by Smith and his associates is the book first published in 1612, *A Map of Virginia, with a description of the Countrey.* . . . The map, whether made by Smith or by Nathaniel Powell or by other members of his party under Smith's direction (Fite and Freeman, 1926, pp. 116-119; Ford, 1924), is a remarkable production considering the conditions under which it was made.[2] It is tolerably accurate geographically and shows the Indian territories and towns. It clearly indicates which parts are based on actual exploration of the ground and which based on reports. I have not seen this interesting point taken into account elsewhere—it is, however, of importance when discussing Smith's observation of topography and geology.[3] The Coastal Plain is shown with almost no relief, but landward from the Fall Line, little hills are shown to mark the more hilly Piedmont. This distinction between Coastal Plain and Piedmont, recognized by Hariot (1588, p. F2; White, 1952, p. 118), is well shown although not described in the text.[4]

The *Description* starts by giving the location of Virginia, landfalls by which it may be reached, the climate, and then a description of the topography, soil, and the various rivers. In describing the kinds of rocks Smith makes very clear that glistening particles are not gold but may easily be so mistaken (1612, p. 3; 1910, p. 49):[5]

> The mountains are of diverse natures, for at the head of the Bay the rocks are of a composition like milnstones. Some of marble, &c. And many peeces of christall we found as throwne downe by water from the mountaines. For in winter these mountaines are covered with much snow, and when it dissolveth the waters fall with such violence, that it causeth great inundations in the narrow valleyes which yet is scarce perceived being once in the rivers. These waters wash from the rocks such glistening tinctures that the ground in some places seemeth as guilded, where both the rocks and the earth are so splendent to behold, *that better judgments then ours might have been perswaded, they contained more then probabilities.*
>
> The vesture of the earth in most places doeth manifestly prove the nature of the soile to be lusty and very rich. The colour of the earth we found in diverse places, resembleth *bole Armoniac, terra sigillata ad lemnia,* Fullers earth, marle, and divers other such appearances. But generally for the most part the earth is a black sandy mould, in some places a fat slimy clay, in other places a very barren gravell. But the best ground is knowne by the vesture it beareth, as by the greatnesse of trees or abundance of weedes, &c.
>
> The country is not mountanous nor yet low but such pleasant plaine hils and fertle valleyes, one prettily crossing an other, and watered so conveniently with their sweete brookes and christall springs, as if art it selfe had devised them.

[2] Brown's (1891) denial of Smith's authorship of the map carries little conviction. The reproduction of the manuscript map he exhibits to show how crude Smith's work probably was is not at all convincing. Many an excellent map is produced by a competent cartographic draftsman from just such rough notes. This is especially true if the author of the map is at hand to confer with cartographer and engraver as the map develops.

[3] Reproductions of the map are given by Arber (1910), Ford (1924) and Fite and Freeman (1926).

[4] Smith's map is not the first to show Coastal Plain and Piedmont. Hariot's map of "Virginia" of 1588 (Lorant, 1946, pp. 274-275) shows a hilly region inland from the coastal region. Le Moyne's map of "Florida" of 1565 (?) (Lorant, pp. 34-35) shows hills beyond a coastal region, placed on the map probably from hearsay.

[5] Each reference to Smith's writings will be given both to the first edition and to the much more accessible Arber edition of 1910.

The spelling and punctuation of the original are retained, except for the long "s" which not even Arber reproduced; and, when required, the substitution of initial "u" for "v", of medial "v" for "u" and of "j" for "i." I feel justified in making these changes because these quotations are for geologists rather than for bibliographers who will consult the original anyway. (The generally rigid, rather than capricious, usage of these letters by early printers is described by McKerrow, 1928, p. 310). Those few comments I have thought necessary to make within the quotations are shown by square brackets [].

The crystalline rocks at "the head of the Bay" are those near Baltimore. The description of soil is probably the first one in English for America. In it Smith clearly recognizes the variation of vegetation with soil types. The *bole Armoniac* and *terra sigillata* are varieties of clay used for pigment and medicine; they are often referred to in writings of the time (Hoover and Hoover, 1912, p. 31, note 10).

After describing the rivers, their valleys and their inhabitants, Smith passes on to a lengthy description of trees, fruits, plants, animals, fishes, and birds. He concludes this summary of the natural history of Virginia by a paragraph on "The Rocks" (1612, p. 15; 1910, p. 61):

> Concerning the entrailes of the earth little can be saide for certainty. There wanted good Refiners: for these that tooke upon them to have skill this way, tooke up the washings from the mounetaines and some moskered shining stones and spangles which the waters brought down; flattering themselves in their own vaine conceits to have bin supposed that they were not, by the meanes of that ore, if it proved as their arts and judgments expected. Only this is certaine, that many regions lying in the same latitude, afford mines very rich of diverse natures. The crust also of these rocks would easily perswade a man to beleeve there are other mines then yron and steele, if there were but meanes and men of experience that knew the mine from *spare* [spar].[6]

We are still uncertain "concerning the entrailes of the earth," although we do know more about rocks at the earth's surface than was known in 1612. Smith is again contemptuously sure that the "shining stones" are not gold. He is disdainful of the "refiners," of whom he had three besides Captain Newport who also had such pretensions.

It is interesting to note that Smith concludes his own part of the book (1612, pp. 37-38; 1910, pp. 82-83) by castigating those who have spread slanderous stories of hardships in Virginia in terms so similar to those used by Hariot in 1588 (p. A4; White, 1952, p. 117) that it is certain he had Hariot's book (or the Debry or Hakluyt reprints) before him when composing this section.

## The "Refiners"

It is necessary to distinguish Part 1 of the 1612 *Description* by Smith himself, which is well written and well organized, from Part 2, which is a collection of partly repetitive writings of seven of the Virginia colonists, of varying length, expression, detail, and literacy. They give first-hand information of events and locations at which Smith was not present. They are in a sense the raw data which Smith in part used for his summary in Part 1.

In Chapter III of Part 2, Anas Todkill and Thomas Studly tell of the arrival (Jan. 8, 1608) of a ship commanded by Captain Newport. Todkill and Studly write disapprovingly of Captain Newport and his sailors. Instead of delivering the supplies and returning, the sailors stayed on for 14 weeks, eating up the supplies they had brought for the settlers, interfering with the indian trade, but to quote Todkill (1612, p. 21, 22; 1910, p. 104; the poetry, not found in the 1612 *Description* but added in the *Generall Historie* [1624, p. 53; 1910, p. 408], shows Smith's continuing bitterness toward Captain Newport):

[6] Smith's last sentence is more comprehensible if we remember "mine" meant "deposit or ore mineral [of]," whence "tell mine from spar" means "tell ore mineral from worthless rock."

But the worst mischiefe was our gilded refiners, with their golden promises, made all men their slaves in hope of recompence. There was no talke, no hope, nor worke, but dig gold, wash gold, refine gold, load gold. Such a brute of gold, as one made fellow [a wag] desired to bee buried in the sandes, least they should by their art make gold of his bones. Little need there was and lesse reason, the ship should stay, their wages run on, our victuall consume 14 weekes, that the Marriners might say, they built such a golden Church, that we can say, the raine washed neare to nothing in 14 daies.

Were it that Captaine *Smith* would not applaud all those golden inventions, because they admitted him not to the sight of their trials, nor golden consultations I knowe not: but I [? Anas Todkill] heard him question with Captaine *Martin* and tell him, except he would shew him a more substantiall triall, hee was not inamored with their durtie skill. Breathing out these and many other passions, never any thing did more torment him, than to see all necessarie businesse neglected, to fraught such a drunken ship with so much gilded durt.

Till then wee never accounted Captaine *Newport* a refiner. Who being fit to set saile for England, and wee not having any use of Parliaments, plaies, petitions, admirals, recorders, interpreters, chronologers, courts of plea, nor Iustices of peace, sent Maister *Wingfield*, and Captaine *Archer* with him, for England, to seeke some place of better imploiment.

*Oh cursed gold, those hunger-starved movers,*
*To what misfortunes lead'st thou all those lovers!*
*For all the* China *wealth, nor Indies can*
*Suffice the minde of an av'ritious man.*

At the end of the Todkill-Studly section (1612, p. 23-29; 1910, p. 106-108) is a list of those who came on April 20, 1608, in the *Phoenix*. This vessel, which Captain Martin wished to load with "phantasticall gold," finally sailed for England with a cargo of cedar which was what Smith intended from the outset she carry home.[7] There were landed from the *Phoenix* 33 "Gent.," 21 "Labourers," 6 "Tailers," 2 "Apothecaries," a "Jeweller," a "Gunsmith," a "Perfumer," 2 "Goldsmiths," 2 "Refiners," 4 other artisans, and "divers others to the number of 120."

The refiners were William Dawson and Abraham Ransacke. Already William Callicut (1612, p. 47; 1910, p. 125) was present and listed as a "refiner." Captain Newport also had pretentions as such and Captain Martin (Brown, 1898, p. 46) was the son of Sir Richard Martin, master of the mint. Yet Newport and Martin, the four refiners, and the two goldsmiths were deluded by the "phantasticall gold" which appears to have been only sand with glittering mica flakes. Throughout his books Smith is always contemptuous of his "refiners" and surely with good reason. They seem to have been far less expert, cautious, conservative, and respected than Captain Vaughan, who was refiner ("minerall man") with Lane and Hariot 20 years earlier, or than the Saxon Daniel, who perished with Sir Humphrey Gilbert a few years before that (White, 1952, p. 119). These refiners with whom Smith was plagued could not have been serious students of Ercker (Sisco and Smith, 1951), Biringuccio (Smith and Gnudi, 1942), or Agricola (Hoover and Hoover, 1912), and knew nothing of the *Probierbuchlein* (Sisco and Smith, 1949).

[7] But see Beverley ([1705], 1947, p. 31), who reports that this ship did carry micaceous dirt—"a yellow sort of Dust-Isinglass"—with a part load of cedar, and that soon after a second ship sailed with this "supposed Gold-Dust, . . . filling her up with Cedar and Clap-board." The report by Todkill may be interpreted either way. Brown (1898, p. 59) asserts that only "samples of minerals" were taken back in these voyages.

Even a touchstone, used alike by assayers, goldsmiths, and jewellers of that day, unreliable as this instrument is for careful assaying, would have shown them that mica is not gold. Had they been resourceful they could even have used a piece of gold coin for a touch needle (Sisco and Smith, 1951, p. 122). An interesting early confirmation of Newport's "gold," followed by more thorough assays in which the worthless samples "turned to vapore," is quoted from a contemporary letter by Brown (1898, p. 45, 46).

The report of Dr. Walter Russell and Anas Todkill on the "Accidents that hapned in the Discoverie of the bay Chesapeake" makes up chapter 5 of Part 2 of *A Map of Virginia*. They relate some details of a voyage up the Potomac River (1612, p. 33; 1910, p. 113):

The cause of this discovery was to search a glistering mettal, the Salvages told vs they had from *Patawomeck* (the which *Newport* assured that he had tryed to hold halfe silver), also to search what furres, metals, rivers, Rockes, nations, woods, fishings, fruits, victuals, and other commodities the land afforded; and whether the bay were endlesse, or how farre it extended.

The mine we found 9 or 10 myles up in the country from the river; but it proved of no value.

Much greater detail of the same report is given in the 1624 *Generall Historie*, which includes a bit more geological observation on the travel to the falls of the Potomac and then later up the Quiyough (Occoquan) River to the Fall Line. They found no precious metals, but the unusual method they used to try to catch fish is amusing (1624, p. 58; 1910, p. 417-418):

Hauing gone so high as we could with the bote, we met divers Salvages in Canowes, well loaden with the flesh of Beares, Deere and other beasts; whereof we had part. Here we found mighty Rocks, growing in some places above the grownd as high as the shrubby trees, and divers other solid quarries of divers tinctures: and divers places where the waters had falne from the high mountaines they had left a tinctured spangled skurfe, that made many bare places seeme as guilded. Digging the growne above in the highest clifts of rocks, we saw it was a claie sand so mingled with yeallow spangles as if it had beene halfe pindust.

In our returne inquiring still for this *Matchqueon*, the king of *Patawomeke* gave us guides to conduct us up a little river called Quiyough, up which we rowed so high as we could. Leaving the bote; with six shot and divers Salvages, he marched seven or eight myle before they came to the mine: leading his hostages in a small chaine they were to have for their paines, being proud so richly to be adorned.

The mine is a great Rocky mountaine like Antimony; wherein they digged a great hole with shells and hatchets: and hard by it, runneth a fayre brooke of Christal-like water, where they wash away the drosse and keepe the remainder, which they put in little baggs and sell it all over the country to paint there bodyes, faces, or Idols; which makes them looke like Blackmores dusted over with silver. With so much as we could carry we returned to our bote, kindly requiting this kinde king and all his kinde people.

The cause of this [voyage of] discovery was to search [for] this mine, of which *Newport* did assure us that those small baggs (we had given him), in England he had tryed [assayed] to hold halfe silver; but all we got proved of no value: also to search what furrs. . . . and what other mineralls, rivers, rocks, nations, woods, fishings, fruites, victuall, and what other commodities the land afforded: and whether the bay were endlesse or how farre it extended.

Of mines we were all ignorant, but a few Bevers, Otters, Beares, Martins and minkes [skins] we found, and in divers places that aboundance of fish, lying so thicke with their heads above the water, as for want of nets (our barge driving amongst them) we attempted to catch them with a frying pan: but we found it a bad instrument to catch fish with: neither better fish, more plenty, nor more variety for smal fish, had any of us ever seene in any place so swimming in the water, but they are not to be caught with frying pans.

Some of Captain Newport's actions after January, 1608, are understandable when we realize that he had secret orders "not to returne without a lumpe of gold, a certainty of the south sea, or one of the lost company of Sir Walter Rawley" (1612, pt. 2, p. 42; 1910, p. 121). He also brought a "5 pieced barge" which was to bear him to the south sea after "we had borne her over the mountaines (which how farre they extend is yet unknown)" (*ibid*). The troublesome Captain Newport was unable to carry out any of his secret orders, but he did disrupt the organization and development of the infant settlement.

The narrative by Richard Wiffen, William Phettiplace, and Anas Todkill also recounts the journey of Captain Newport (Smith stayed behind) to Monacan 40 miles beyond the falls of the Powhatan (James) River at the present site of Richmond and the search on the return for minerals. They also recount how William Callicut, "a refiner, fitted for that purpose . . . perswaded us to beleeve he extracted some smal quantitie of silver (and not unlikely better stuffe might bee had for the digging)" (1612, p. 47; 1910, p. 125, 126). That these men had read of the great riches won by the Spaniards in Richard Eden's *Decades of the New World* in the 1555 or 1577 edition or in one of the editions of Hakluyt is indicated by the conclusion of their report (1612, pt. 2, p. 77, 78; 1910, p. 148):

> But to conclude, against all rumor of opinion I only say this for those that the three first yeares began this plantation: notwithstanding al their factions, mutenies, and miseries, so gently corrected and well prevented, peruse the Spanish *Decades*, the relations of *Master Hacklut;* and tell mee how many ever, with such smal meanes as a barge of 2 Tunnes, sometimes with 7, 8, 9, or but at most 15 men, did ever discover so many faire and navigable rivers, subject so many severall kings people and nations to obedience and contribution, with so little bloud shed.
>
> And if in the search of those Countries, wee had hapned where wealth had beene, we had as surely had it, as obedience and contribution; but if wee have overskipped it, we will not envy them that shall chance to finde it. Yet can wee not but lament it was our ill fortunes to end, when wee had but only learned how to begin, and found the right course how to proceed.

Eight Dutchmen and Poles came with Newport in 1608 (1612, p. 53; 1910, p. 129) to make pitch, tar, glass, and "sope ashes." On his return Newport took "tryals" of these (1612, p. 51; 1910, p. 128). Some of the Dutchmen sold arms to the Indians and joined them for a time (1612, p. 65; 1910, p. 139). "The randavus for all their unsuspected villany" was "the glasse-house, a place in the woods neere a myle from *James* Towne . . ." (1612, p. 80; 1910, p. 150). Thus early in American history came the use of industrial minerals in manufactures.

## New England

Captain John Smith left Virginia for England in 1609, never to return to the colony which would not have survived the rigors of the winters of 1607 and 1608 without his guidance. After several years in England, during which he wrote his famous book on Virginia (1612) and defended himself from stories of his enemies, he returned to British America, but to a more northeasterly part of it. Smith explored briefly the New England coast in 1614, but his return in 1615 was prevented by storms and his capture by the

French. Quite characteristically, during his captivity and upon his return he wrote a book: *A Description of New England* . . . (1616). In the first page of his book, in which he names New England for the first time, Smith gives the reasons for this voyage to America (1616, p. 1; 1910, p. 187):

> In the moneth of Aprill, 1614. with two Ships from *London*, of a few Marchants, I chanced to arrive in *New-England*, a parte of *Ameryca;* at the Ile of *Monahigan*, in 43½ of Northerly latitude; our plot was there to take Whales and make tryalls of a Myne of Gold and Copper. If those failed, Fish and Furres was then our refuge . . .
>
> For our Golde, it was rather the Masters device to get a voyage that projected it, then any knowledge hee had at all of any such matter.

His succinct summary of the explorations, and his estimation of the extent of knowledge of America from Florida northward, is very useful (1616, pp. 3, 4; 1910, p. 189). He mentions the character of the coast south of Pennobscot and contrasts the rocky coast of Maine with the sandy shores of Massachusetts. He generalizes on mineral resources from quite insufficient direct evidence, but his statement shows that he and his party did pay some attention to these matters (1616, p. 9; 1910, p. 193):

> From *Pennobscot* to *Sagadahock* [cf. Sagadahoc County at mouth of Kennebec River] this Coast is all Mountainous and Iles of huge Rocks, but overgrowen with all sorts of excellent good woodes . . .
>
> Betwixt *Sagadahock* and *Sawocatuck* [? Cape Porpoise] there is but two or three sandy Bayes, but betwixt that and *Cape Cod* very many: especialy the Coast of the *Massachusets* is so indifferently mixed with high clayie or sandy cliffes in one place, and then tracts of large long ledges of divers sorts, and quarries of stones in other places so strangely divided with tinctured veines of divers colours: as, Free stone for building, Slate for tiling, smooth stone to make Fornaces and Forges for glasse or iron, and iron ore sufficient, conveniently to melt in them. But the most part so resembleth the Coast of *Devonshire*, I think most of the cliffes would make such lime stone. If they be not of these qualities, they are so like, they may deceive a better judgment then mine. All which are so neere adjoyning to those other advantages I observed in these parts, that if the Ore prove as good iron and steele in those parts, as I know it is within the bounds of the Countrey, I dare engage my head (having but men skilfull to worke the simples there growing) to have all things belonging to the building [and] the rigging of shippes of any proportion, and good marchandize for the fraight, within a square of 10 or 14 leagues. . . .

The description of the geography and natural history of New England is not so smoothly organized as the earlier one of Virginia, but nevertheless is full of information. He apparently did not have an assayer ("mineral man" or "refiner") along on this voyage to New England, but acted as his own assayer. He apparently had had instruction in assaying and probably had instructions along with him. However, we get the impression that Smith really did not expect to find precious metals. Always one to emphasize the more immediate and known resources, such as fish and furs, he knew at first hand about iron ore and knew it could be important to a new colony. At any rate he was sure of iron if not of gold (1616, pp. 20, 21; 1910, p. 201):

> Of Mynes of Golde and Silver, Copper, and probabilities of Lead, Christall and Allum, I could say much if relations were good assurances. It is true indeed, I made many trials, according to those instructions I had, which doe perswade mee I need not despaire, but there are metalls in the Countrey: but I am no Alchymist, nor will promise more then I know: which is, Who will undertake the rectifying [? erecting] of an Iron forge, if those that buy meate, drinke,

coals, ore, and all necessaries at a dear rate gaine; where all these things are to be had for the taking up, in my opinion cannot lose.

In his *Description of New England* Smith included a map which is as remarkable as his earlier map of Virginia. It is the first real map of this part of North America. It does not show the interior as well as the map of Virginia, but it must be remembered that he spent far less time in New England than in Virginia. No special geological implication can be read from the map of New England as can be from that of Virginia.

## Conclusion

Smith wrote still other books, which, however, are mainly restatements of his earlier works on Virginia and New England. The most important is *The Generall Historie of Virginia, New England and the Summer Isles* of 1624. In a complete study, they must be examined because there is an occasional amplification, amendment, or addition.

In his maps and books about the new land, Smith supplied clear and factual information for English readers. Intelligent Englishmen could no longer hold the extravagant and fantastic ideas of the New World portrayed in the well-known play of 1605, *Eastward Hoe.*

Smith's report and maps indicate he was aware of the existence of a low region of sand and clay (Coastal Plain) beyond which lay a more hilly belt (Piedmont) with rivers passing from hilly belt to the lower part by falls. Crystalline rock outcropped at falls and upstream from the falls. Mineral resources included clay, building stone, iron ore, limestone, and materials for glass making. Smith's careful and repeated denial of precious metals was a factor in bringing the English to their senses about the prospects of wealth in the new land; already by 1634 Wood, and by 1637 Morton, accepted the very probable nonexistence of precious metals in New England.

John Smith was a keen observer of natural history but, unlike Hariot, his scientific observations were only incidental to his major activities as soldier, sailor, explorer, administrator, colonizer, and writer. Less credulous than most, he realized that in America the English had a world primarily for settlement rather than for exploitation of any precious metal. He shrugged off precious metals as unimportant, as compared to fertile soil and fundamental resources of iron and fuel to smelt it. He had the keen eye of the successful soldier for topography, but not the scholar's contemplative consideration of its continuity and origin, as did Hariot. He had the scientific spirit of true report of data. He left to others analysis and theory.

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# REVISION OF THE NIPISSING STAGE OF THE GREAT LAKES

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The records of glacial and postglacial lakes in the Great Lakes region were studied intensively by a number of geologists in the latter part of the nineteenth century and during the first decade of the twentieth century. The results were presented in the United States Geological Survey Monograph 53, by Leverett and Taylor, in 1915. During the next 20 years there were no important contributions to the subject, and the Great Lakes history as presented by Leverett and Taylor came to be widely accepted. Modern textbooks of historical geology give the Leverett and Taylor version of the Great Lakes history.

The first serious revision of the generally accepted history, and one involving the Nipissing stage, was made by Stanley in 1936. Bretz published additional revisions in 1951, and the writer recently has completed a two-year study of various Great Lakes features (Hough, 1953). During the past three years a few radiocarbon dates have been obtained for events in the later lake history (Arnold and Libby, 1951; Libby, 1951; Libby, 1952).

A revision of the Nipissing stage, required by some of the new information, should be of interest not only to geologists but to archeologists, because human occupational sites have been found associated with the Nipissing and related beaches.

## The Leverett and Taylor History

In the history presented by Leverett and Taylor (1915), the Nipissing Great Lakes existed as the last generally well-defined stage before the lakes in the Michigan and Huron basins reached their present elevation. In the northern parts of the Michigan and Huron basins and in the southern part of the Superior basin the Nipissing beach is one of the most strongly developed shores of the Great Lakes region. This beach has been tilted by earth movement since it was formed, and it occurs at successively higher levels to the north. Gilbert, in 1898 (p. 605), as well as Spencer and Taylor in their early writings, states that the Nipissing beach descended below present lake level in the southern parts of the Michigan and Huron basins. Taylor (in Leverett and Taylor, 1915) later stated that the Nipissing beach of the north descended to an elevation of about 15 feet above present lake level and extended throughout the southern parts of the Michigan and Huron basins at that elevation. A correlation thus was made between the strong Nipissing beach of the north and a weak beach at an elevation of 596 above sea level in the south.

The Nipissing Great Lakes, according to Leverett and Taylor, were preceded by a complicated series of

Algonquin lake stages which existed while glacial ice stood in the lake basins, forming some part of the northern shore. These stages may be summarized as follows:

Algonquin I, at an elevation of 605 feet, discharged southward both at Chicago and at Port Huron; Algonquin II, at an elevation perhaps as much as 100 feet lower, discharged at Kirkfield, Ontario, to the Trent Valley; Algonquin III, at an elevation of 605 feet (because upwarp of the land raised the Kirkfield outlet), discharged at the old Chicago and Port Huron outlets; "Lower Algonquin" stages formed in the northern parts of the region while upwarp of the land to the north was in progress, but the lake continued to discharge through the Chicago and Port Huron outlets and the lake surface remained at the same elevation (605 feet). Figure 1 shows the Algonquin III beach and the "lower Algonquin" beaches converging to the single Algonquin level in the south, as described by Leverett and Taylor.

The original stage of Lake Nipissing came into existence, according to Leverett and Taylor, when glacial ice retreated from the Mattawa-Ottawa valley and permitted the lake to drain through a new outlet at North Bay, Ontario. This was the "one-outlet" stage, and it stood at an elevation of "530 ±" feet (Leverett and Taylor, 1915, p. 469) or about 50 feet below present lake level. Upwarp of the land to the north raised the North Bay outlet, and the lake surface rose until the water discharged to the south through the old Port Huron outlet. It was assumed that the sill of the Port Huron outlet somehow had been lowered, during the period when no discharge occurred there, from the old Algonquin level to a level which stopped the rising Nipissing waters at an elevation of 596 feet. The main Nipissing stage, or the Nipissing Great Lakes, then remained at that elevation and discharged both at North Bay and at Port Huron. Following this stage the lake surface

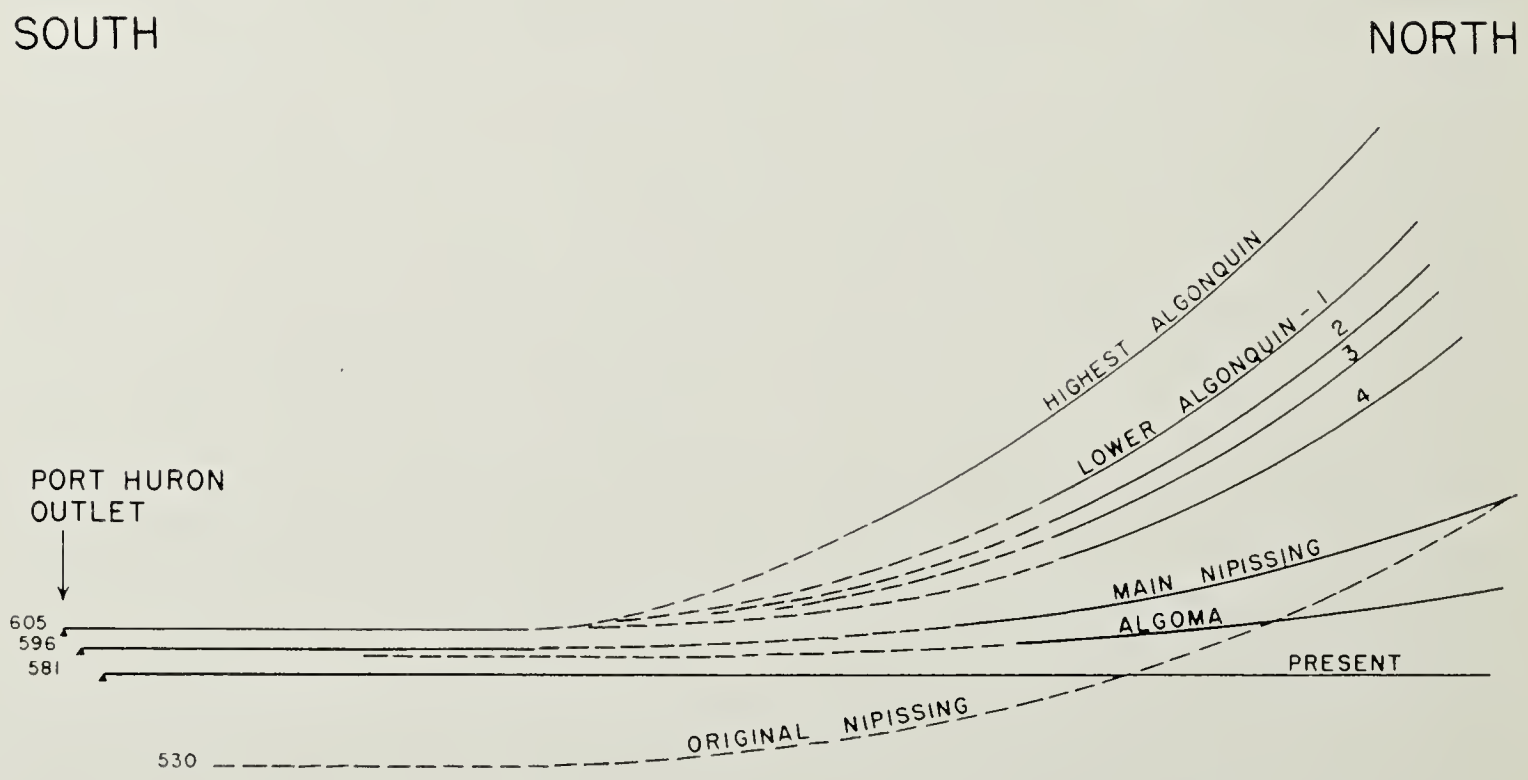


FIG. 1.—Correlation of warped northern beaches with horizontal southern beaches in the Huron basin, according to Leverett and Taylor.

was lowered, by erosion of the Port Huron outlet, to the present elevation of Lakes Michigan and Huron, pausing at intermediate levels long enough to cut the Algoma beach and a few other faint beaches.

Some more recent studies, to be described later, have shown that certain steps in the foregoing history are incorrect. With this knowledge in mind, a critical reading of the Leverett and Taylor monograph (1915) reveals that almost the entire history from the Algonquin to the present synthesized by those authors consists of statements which are not supported by field evidence. The parts of the history which are based on direct field evidence are as follows: Algonquin stage III is represented by a fairly extensive beach, the "lower Algonquin" stages are represented by discontinuous beach features in the north, and the "two-outlet" Nipissing stage is represented by a strong beach in the north and by a weak beach in the south. The various outlets involved obviously were in use at some time in the history. Correlations between northern and southern beaches are questionable, however, and the detailed interpretation of events as presented in this history is not supported by facts.

## The Stanley Revision

In 1936 Stanley showed that the "lower Algonquin" beaches of Leverett and Taylor, or their apparent correlatives in the Georgian Bay area, do not converge to the south but are essentially parallel. They descend below present lake level, instead of converging on the "highest" Algonquin beach at an elevation of 605 feet. The Nipissing beach cuts across the "lower Algonquin" beaches. These relationships are shown in figure 2.

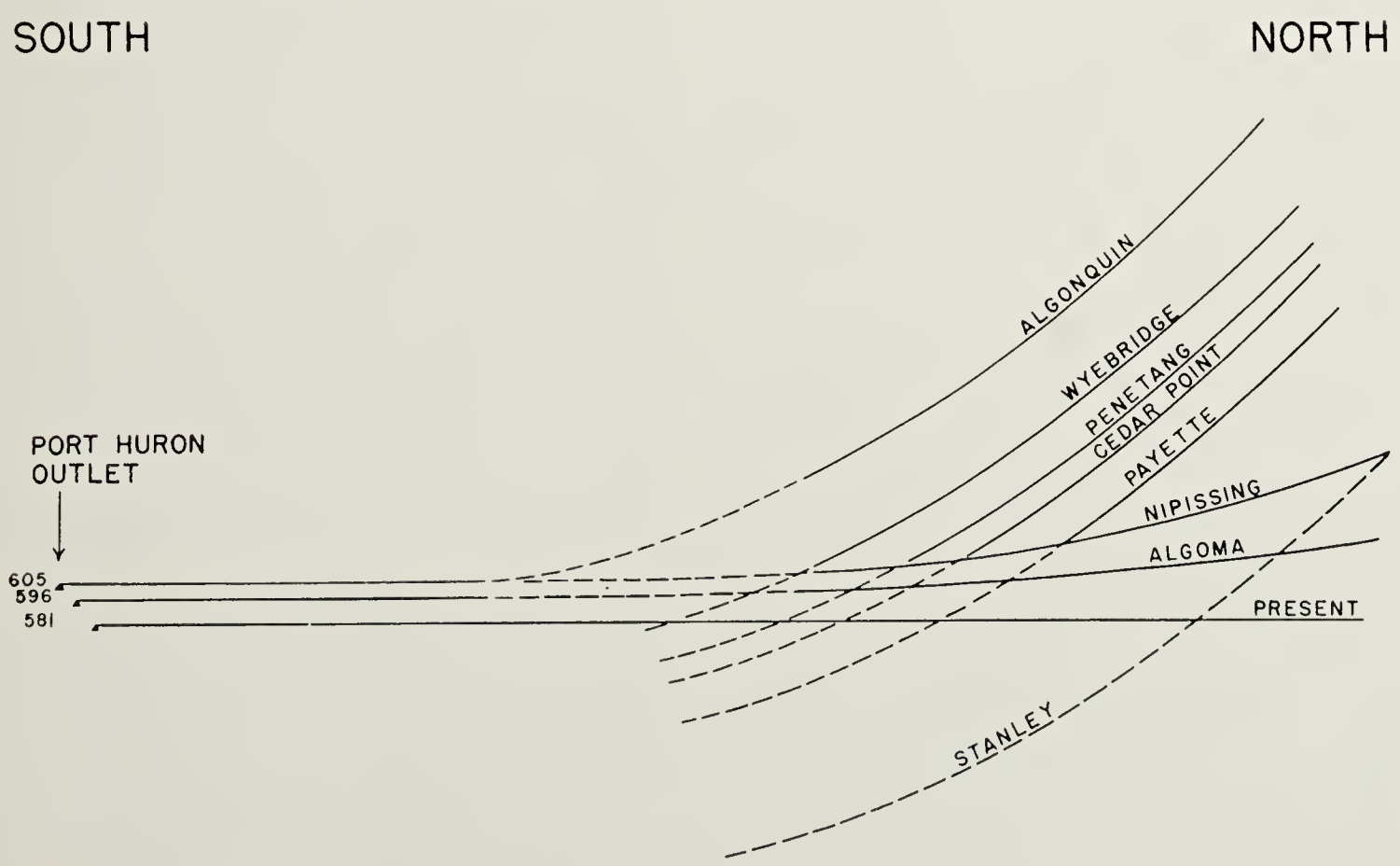


Fig. 2.—Correlation of warped northern beaches with horizontal southern beaches in the Huron basin, according to Hough (modified from the Stanley interpretation).

The logical interpretation of this information is that the lake level must have been lowered by drainage through new, successively lower, outlets and that no appreciable upwarp occurred until after the entire Algonquin series was formed. A further consequence is that when glacial ice retreated from the North Bay area the lake surface may have been lowered nearly to sea level. This is suggested by the relationship of the "lowest Algonquin" (Payette stage of G. M. Stanley) to the highest (main) Algonquin beach; it is parallel and 190 feet lower. The lake surface was lowered from an elevation of 605 feet to 415 feet before upwarp occurred. Stanley suggested that upwarp may have begun considerably later than the Payette stage, and that the lake surface may have been much lower. Stanley then (1938) pointed out a channel in the floor of the Straits of Mackinac, connecting the Michigan and Huron basins, which has a present minimum depth of approximately 150 feet, and calculated that the channel bottom before upwarp was at an elevation of approximately 230 feet, or 350 feet below present lake surface. This means that Lake Michigan may have been at an elevation of 230 feet; Lake Huron may have been still lower, because the channel is recognizable as a feature which extends downward into the Huron basin.

Stanley's work was confirmed by Deane (1950), who likewise found an essential parallelism of the beaches from the (highest) Algonquin down to, but not including, the Nipissing.

One consequence of accepting the work of Stanley and Deane is that the Leverett and Taylor Algonquin stage II (the low-water stage between Algonquin I and III) should be abandoned for a lack of supporting evidence. Algonquin I and III thus merge into a single Algonquin stage. This detail has no immediate bearing on the Nipissing stage, however, and will not be discussed further in the present paper.

## Pre-Nipissing Low-Water Stage

The pre-Nipissing low-water stage postulated by Stanley has been confirmed by the writer; coarse-grained sediment and shallow-water organisms were found in the Lake Michigan bottom deposits down to a depth of 350 feet (Hough, 1952). The low stage in the Lake Michigan basin has been named Lake Chippewa. The existence of Lake Chippewa requires a low stage in the Huron basin also, which has been named Lake Stanley in recognition of G. M. Stanley's work.

The Leverett and Taylor hypothetical "original Nipissing" stage occupied a somewhat similar position in the history that Lakes Chippewa and Stanley now occupy. The "original Nipissing," however, was conceived as following the greater part of the post-Algonquin uplift, and the lake surface was stated to be at an elevation of approximately 530 feet. It is proposed that the term "original Nipissing" be abandoned, and that "Nipissing" be restricted to a later stage when the lake surface was raised back to the level of a southern outlet.

## Transition to the Nipissing Stage

Following the extreme low-water stage, Lakes Chippewa and Stanley, there was uplift of the land to the

north, warping the old beaches and raising the North Bay outlet. The lake surface was raised until the water discharged to the south, after which no further rise in lake level was possible. This period of rise from the Chippewa-Stanley low levels to the level of the southern outlet is a transitional stage, and the term "Nipissing" is here applied to the stage of static level which followed the transition.

## North-South Correlation of the Nipissing Beaches

None of the old beaches in the northern parts of the Michigan and Huron basins can be traced to a junction with any of the beaches in the southern parts of the basins. Erosion has removed all the old beaches above present lake level on both sides of the Michigan and the Huron basins in the critical areas where the tilted northern portions approach horizontality. This fact may be gleaned from the Leverett and Taylor monograph only by very careful study. There is thus no direct field evidence for making correlations between the northern and southern beaches.

As stated in the foregoing summary of the Leverett and Taylor history, Taylor and others at one time had postulated that the generally accepted Nipissing beach in the north, in the warped area, descended below lake level in the south. When Taylor later stated that the Nipissing beach descended from the north to a position of horizontality above present lake level at an elevation of 596 feet, he had no further field evidence on which to base his revision. It appeared to be a more logical deduction in view of his current concept of lake history. With nothing more substantial to support it, Taylor's level for the Nipissing stage is not defensible.

The writer has made a new revision in which the Nipissing beach becomes horizontal above present lake level at 605 feet. This not only appears to be logical in his concept of lake history, and to be a correlation of northern and southern beaches which compare more favorably in strength of development; it is supported by radiocarbon dates obtained for beach materials in both the northern and southern areas. The reasoning which led to the supposition that the Nipissing stage stood at 605 feet, the old Algonquin level, will be summarized before supporting data are presented.

## The Nipissing Stage

Resorting to an arm-chair analysis, the writer reasoned that the Nipissing stage should have existed at the same elevation as did the earlier Algonquin stage. This reasoning is as follows: the discharge of the Algonquin stage (Algonquin I and III of Leverett and Taylor) passed through the southern outlets, without cutting them down, for a long period of time during which the strong Algonquin beach was formed throughout much of the Michigan and Huron basins. The outlet channels apparently were stabilized in relation to the discharge of Lake Algonquin, and a greater volume of discharge would be required to initiate downcutting. No source of greater discharge late in the Algonquin stage is known. In view of the work of Stanley, Deane, and the writer it appears that the lake waters

were drained down to successively lower levels, including the Chippewa-Stanley low-water stage, before any appreciable upwarping in the north, and that the drainage was through new lower outlets to the east and to the northeast. The Chicago and Port Huron outlets presumably were abandoned while they were still at the level which had controlled the Algonquin stage.

When the water rose to the Nipissing stage it presumably would have found the outlets at the same elevation they had had when they were abandoned. Because the Nipissing-stage lake drained largely through the North Bay outlet at first, and only slowly sent additional quantities of water to the south (because of the slow rise of the North Bay outlet), the initial cutting power of the Nipissing discharge through the Port Huron outlet would have been less than that of the Algonquin discharge. The strong development of a single Nipissing beach in the north indicates that the Nipissing stage was comparatively long and stable. When the North Bay outlet was raised sufficiently, the entire Nipissing discharge (from all of the upper lake basins) was finally diverted to the south. At this time downcutting of the Port Huron outlet was begun (the Chicago outlet was on bedrock), which terminated the Nipissing stage.

According to the foregoing reasoning, the Nipissing-stage lake occupied the old Algonquin beach in the southern, unwarped portions of the Michigan and Huron basins. This conclusion is supported by a comparison of the generally accepted Nipissing beach of the north, which is a strongly developed feature, with the Algonquin level (605 foot) beach of the south, which also is a strongly developed feature. The beach at 596 feet in the south, which Leverett and Taylor designated as Nipissing, is a much weaker feature and compares more favorably with the Algoma beach of the northern areas, which lies in a position between the Nipissing and the present lake level.

## Radiocarbon Dates

When the radiocarbon dates for various beach features in the Great Lakes region (Arnold and Libby, 1951; Libby, 1951; Libby, 1952) are first assembled, they do not fall into a reasonable sequence. The dated events as identified in the original reports are listed below:

| | *Age in years* |
|---|---|
| Mankato glacial substage maximum | 11,000 |
| Lake Grassmere beach (Erie basin, approximately correlative with Toleston beach of Michigan basin | 8,513 ± 500 |
| "Toleston level beach" (605 ft.) in Chicago area | 3,469 ± 230 |
| Nipissing beach, Lake Superior basin | 3,656 ± 640 |
| Nipissing level (594 ft.), Burley site, Lake Huron | 2,619 ± 220 |

If, however, it is assumed that the Nipissing-stage lake rose to the Algonquin level (605 feet), as suggested in the foregoing discussion, and the names of the beaches are adjusted accordingly, the radiocarbon dates fall into the correct sequence:

| | *Age in years* |
|---|---|
| Mankato glacial substage maximum | 11,000 |
| Lake Grassmere beach (Toleston) | 8,513 ± 500 |
| Nipissing beach, Lake Superior basin | 3,656 ± 640 |
| Nipissing beach ("Toleston level" beach, 605 foot) in Chicago area | 3,469 ± 230 |
| Algoma level (594 foot), Burley site, Lake Huron | 2,619 ± 220 |

It is concluded that the Nipissing stage occurred about 3,500 years ago at an elevation of 605 feet above sea level, and that the Algoma stage occurred nearly a thousand years later at an elevation of 596 feet.

## Transition From Nipissing to Present

During the lowering of lake level from the Nipissing stage to the present (by downcutting of the Port Huron outlet), there was one well-defined static period, during which the Algoma beach was formed. In the northern areas, where the identity of the Nipissing beach is unquestioned, the Algoma beach is recognized as a lower beach of moderately strong development. It, like the Nipissing, is warped upward to the north, but it rises at a gentler rate. It is this beach that the writer correlates with the 596-foot beach in the southern, unwarped areas.

The cause of the Algoma static period is not definitely known, but a detailed study of the St. Clair-Detroit River outlet channel by Leverett and Taylor (1915, pp. 494-495) provides a possible explanation. It is evident that in comparatively recent time the Detroit River has shifted laterally from a bedrock-floored portion of its channel to a new location on unconsolidated material, and in making the shift has locally increased its gradient. The writer suggests that this channel shift may be related to the Algoma stage. During the lowering from the Nipissing to the present, the outlet channel may have become graded to the temporary base-level of the bedrock section of the channel, and thus have held the lake at the Algoma level. Downcutting began again after the lateral shift, and the gradient of the channel was adjusted to a lower base-level, causing a drop in lake level.

Faint discontinuous beaches between the Algoma and the present levels presumably record brief static periods, but no explanation for these is known.

## Discussion of the Burley Site

The date for the 594-foot level at the Burley site (Port Franks, Ontario), near the southeastern shore of Lake Huron, was obtained by radiocarbon analysis (Libby, 1952) of charcoal taken from a site of human occupation. The charcoal was associated with evidences of a prehistoric people in the first or lowest occupational stratum. Two additional occupational strata occur at higher levels and contain records of more advanced cultures (Jury and Jury, 1952). A geological study of the Burley site made by Dreimanis (in Jury and Jury, 1952, pp. 72-75) showed the following section:

| *Horizon* | *Elevation of base above sea level* |
|---|---|
| g. Wind-blown sand | 600 |
| f. Dark sand (3rd occupational layer) | 599 |
| e. Wind-blown (?) sand | 598 |
| d. Dark layer (2nd occupational layer) | 597 |
| c. Stratified alluvial sand | 595 |
| b. Dark sand (1st occupational layer) | 594 |
| a. Sand | |

The approximate elevation above sea level of the base of each horizon is given as calculated by the present writer from data on the elevation of the top of horizon b and the average thickness of the other horizons, as reported by Dreimanis. Dreimanis, following Goldthwait (1910, p. 18) and

Taylor (Leverett and Taylor, 1915, pp. 449 and 459), as most students of Great Lakes history have done, accepted a Nipissing identification for the 596-feet beaches and therefore assigned an early Nipissing age to the dated horizon at 594-595 feet. He stated that the dated horizon (b) was occupied in early Nipissing time, that the lake level then rose to 15 feet above the present level (to elevation 596), and the former living site (b) became flooded and covered by alluvial sand with intercalated streaks and lenses of plant remains (horizon c); then the lake level lowered and the river terrace became inhabited again (horizon d). Apparently wind-blown sand (horizon e) covered the second occupational stratum, a third occupational stratum (f) then developed and this, in turn, was covered by wind-blown sand (horizon g).

The present writer suggests a different interpretation of the Burley site stratigraphic section. The Nipissing stage stood at an elevation of 605 feet, water level then was lowered to the Algoma stage (elevation approximately 596 feet), and after a further slight lowering the Burley site was first occupied. Because the Burley site is on a river deposit a mile from the lake, the alluvium (c) which covered the first occupational horizon (b) could accumulate without requiring a rise in lake level. All subsequently deposited cover appears to be of wind-blown origin.

This interpretation is compatible with the writer's conclusion that the Nipissing stage occurred about 3,500 years ago at an elevation of 605 feet above sea level and that the Algoma stage occurred about 2,600 years ago at an elevation of 596 feet above sea level. The Burley site, therefore, apparently was first occupied during late Algoma time.

## Summary

High-water stages preceding the Nipissing are represented by the Toleston beach in the Michigan basin, at an elevation of 605 feet above sea level, and by the early Algonquin beach in the Huron basin at approximately the same level; these were merged into a single lake, the Algonquin stage, at elevation 605 feet, by retreat of the ice from the Little Traverse Bay–Lake Huron lowland. The Algonquin-stage lake discharged at Chicago and at Port Huron.

The Algonquin stage terminated when retreat of glacial ice uncovered a new lower outlet at Kirkfield, Ontario. The lake waters drained down below the level of the southern outlets, leaving them at their Algonquin-stage elevations.

Successively lower lake stages discharging through successively lower outlets followed, until the extremely low Lakes Chippewa and Stanley existed in the Michigan and Huron basins, respectively. These discharged at North Bay, Ontario. Upwarp of the land to the north then occurred, raising the North Bay outlet and raising the water level in the Michigan and Huron basins. When the North Bay outlet was raised to the elevation of the old southern outlets, discharge occurred at three points: North Bay, Port Huron, and Chicago. This initiated the Nipissing stage. The elevation of the Nipissing lake was the same as that of the preceding Algonquin stage, 605 feet above sea level, because its elevation

was determined by the southern outlets which had been abandoned at the Algonquin level.

In the southern half of the Michigan basin three lake stages stood at the 605-foot beach: the Toleston, the immediately succeeding Algonquin, and the post-low stage Nipissing. In the southern part of the Huron basin the early Algonquin, the Algonquin, and the Nipissing stood at the 605-foot beach. Farther north, upwarp of the land raised the older beaches, and the Nipissing beach was formed at a level which cut across the older beaches. Further uplift occurred after Nipissing time, so that the Nipissing beach now also rises to the north but not as steeply as the older beaches. Downcutting of the Port Huron outlet, probably caused by diversion of the entire Nipissing discharge to the south when the North Bay outlet was raised above lake level, terminated the Nipissing stage. The level of the lowering lake was stabilized for a time at an elevation 596 feet above sea level, when the Algoma beach was formed. The cause of this static period is not definitely known, but it may have been because the outlet channel was stabilized on bedrock until the outlet channel shifted laterally to unconsolidated material. Further downcutting of the channel lowered the water to the present elevation of lakes Michigan and Huron.

The Nipissing stage is dated as about 3,500 years old, and the Algoma stage is dated as about 2,600 years old, by radiocarbon analysis.

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# AREAL GEOLOGY OF PART OF CENTRAL EASTERN ILLINOIS*

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Bedrock outcrops are scarce in central-eastern Illinois, which is covered by glacial drift. Samples from wells in this area show that rock formations of Silurian, Devonian, Mississippian, and Pennsylvanian age underlie the glacial drift. Except in a few limited areas, the wells are widely scattered. In order to map the areal distribution of the systems beneath the drift, it is necessary (1) to reconstruct the topography of the bedrock surface on which the drift was deposited and (2) to determine the geologic structure which controls the intercepts of the systems with the bedrock surface. Previous areal maps of this area (Weller, 1945) have shown the general structure of the area, but little consideration was given to the variations in bedrock topography.

The bedrock topography of Illinois was mapped by Horberg (1950). In central-eastern Illinois, present topography (fig. 1) shows little relation to the bedrock topography (fig. 2), which was mapped almost entirely on the basis of well data. The major feature of the bedrock surface is the preglacial Mahomet (Teays) bedrock valley. It crosses the area from the southeast corner of Iroquois county westward across southern Ford and northern Champaign counties, and then trends southwest to central Piatt county, thence to the present Illinois River valley in Mason County. The Danville preglacial valley extends northward across Vermilion County to join the Mahomet valley. The Pesotum preglacial valley extends across Douglas and southern Champaign counties to join the Mahomet valley in Piatt County.

The topography has an areal relief of about 300 feet. It is drained by the Sangamon, Embarass, and Vermilion rivers. The drainage pattern is not related to the bedrock topography, which has about 400 feet of relief and is rougher than the present surface.

Because the top of the Devonian limestone is one of the most persistent subsurface horizons easily identified in samples from wells drilled in the area, it is used as the horizon for mapping the structure (fig. 3). The LaSalle anticlinal belt crosses central-eastern Illinois from north to south. It has a structural relief of at least 2,400 feet. The dip on the west side of the LaSalle anticlinal belt, is relatively steep toward Illinois basin whereas it is more gentle on the eastern side. The doming of the anticlinal belt brings to the bedrock surface formations that range in age from Silurian to Mississippian. To the east, the Oakland anticlinal belt lies almost parallel to the LaSalle anticlinal belt beyond which is the Marshall-Sidell syncline.

In constructing the geologic map, well records were considered the primary data. The structure and bed-

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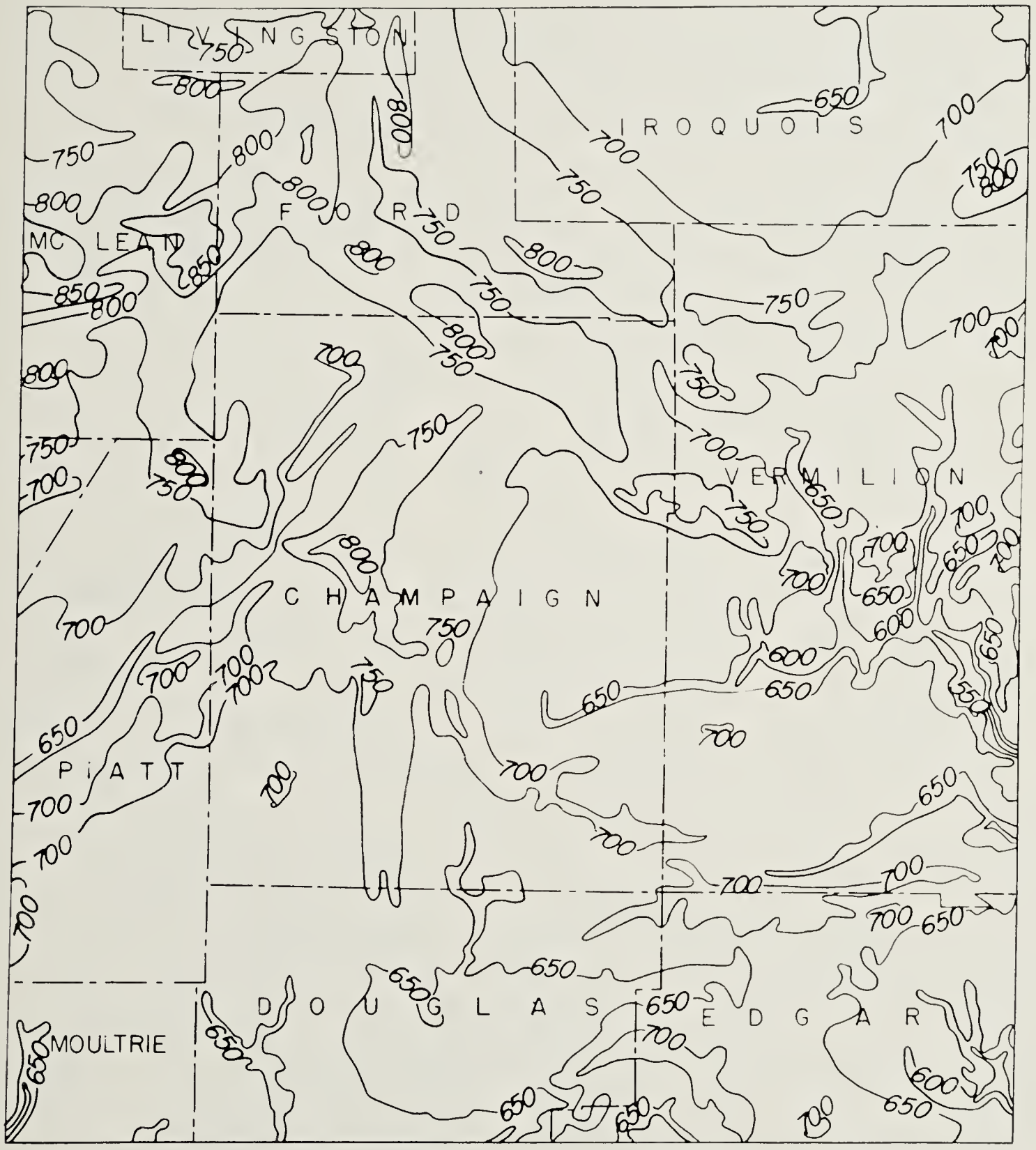
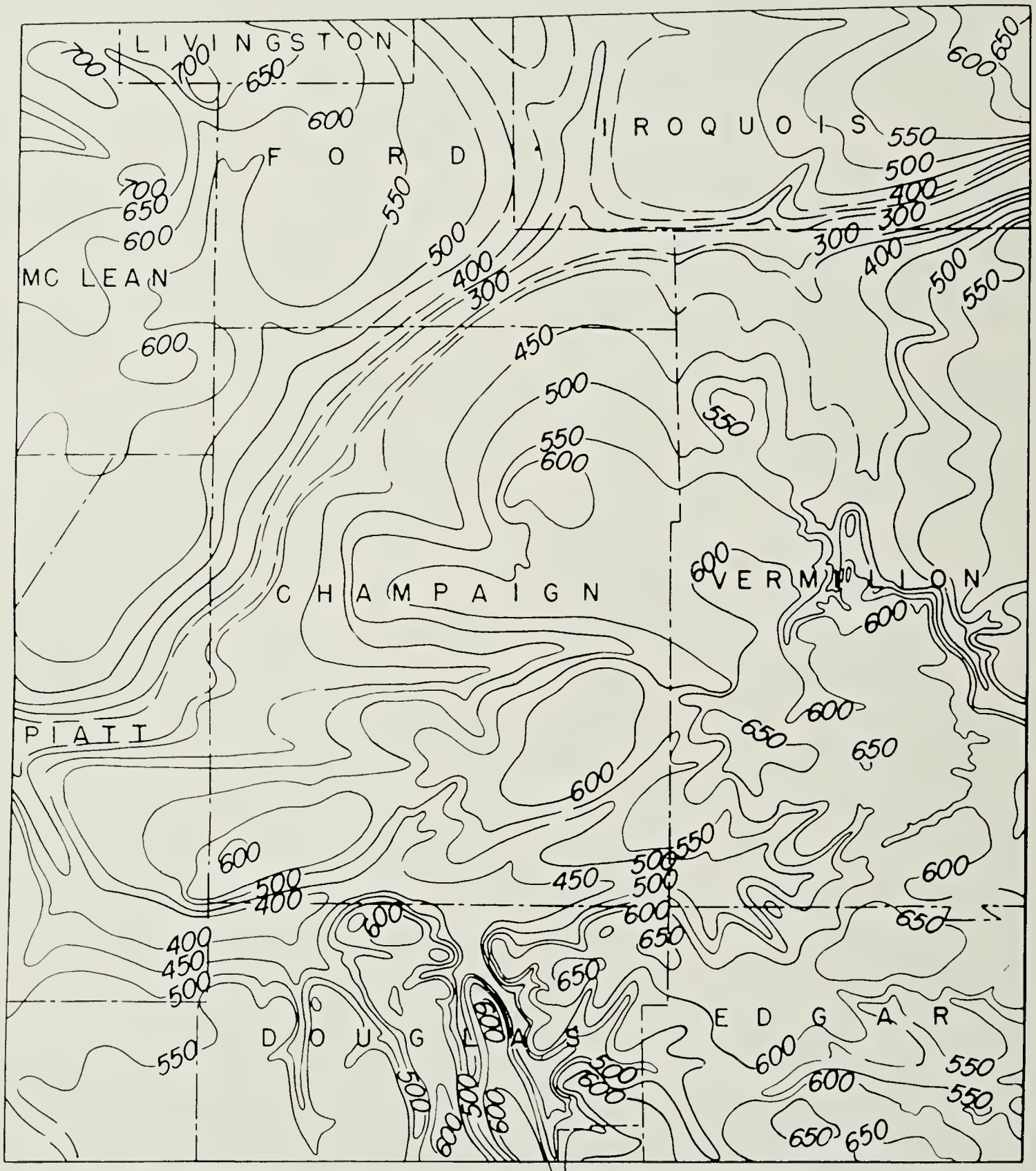



TOPOGRAPHY of PART of CENTRAL EASTERN ILLINOIS
Contour interval 50 feet; datum sea-level

Fig. 1

rock topography maps were used to control the trends of the boundaries and the distance which they were projected along the bedrock valleys.

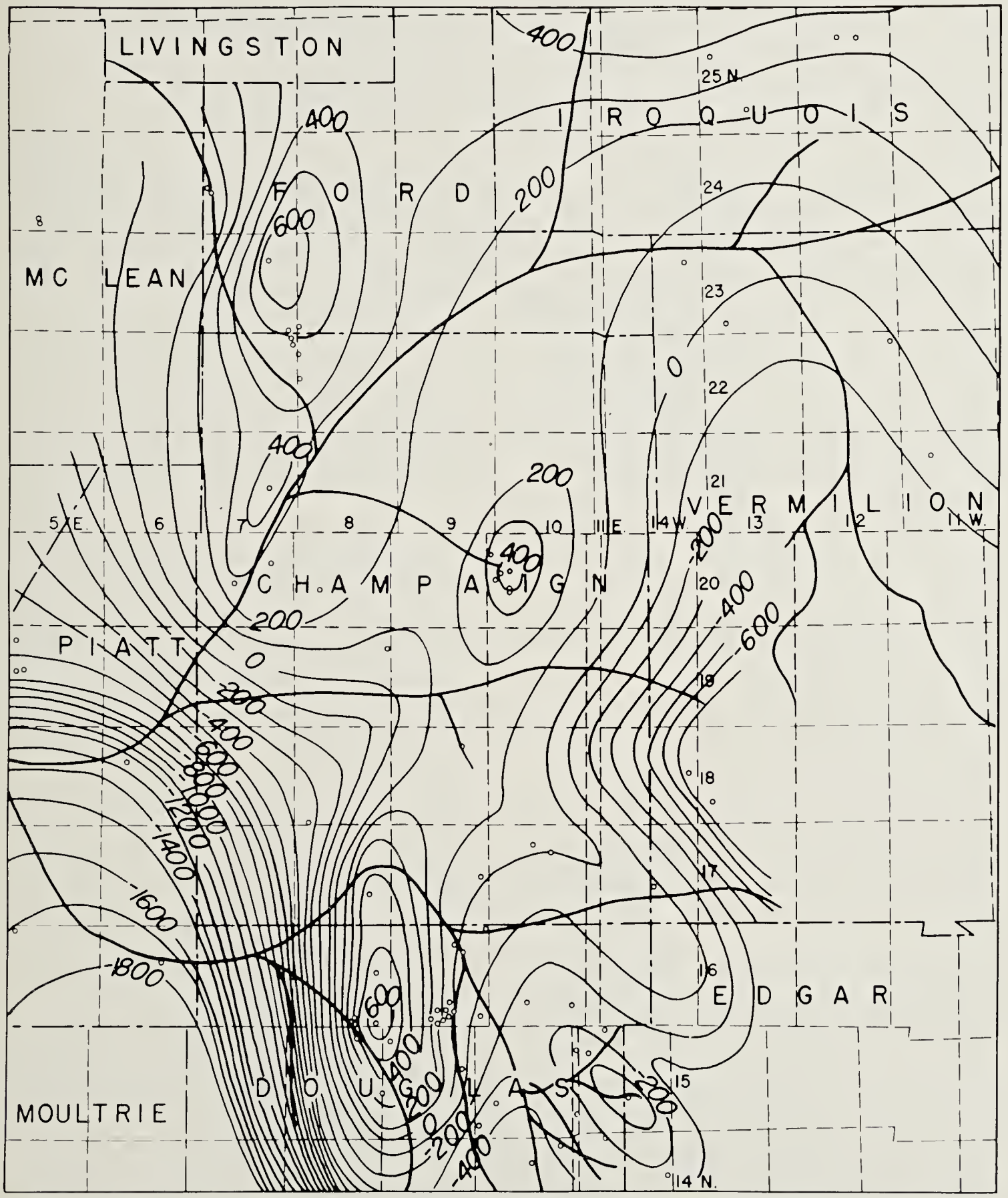
The influence of the Mahomet (Teays) bedrock valley is indicated on the areal geology map (fig. 4) by the northeastern and southwestern elongation of the Silurian and Devonian systems exposed on the bedrock surface of the Gibson City dome in northern Champaign and southern Ford counties. A tongue of Devonian and Mississippian rocks is also projected into the southeastern corner of Iroquois County where the Mahomet valley extends from Illinois into Indiana.




BEDROCK TOPOGRAPHY of PART of CENTRAL EASTERN ILLINOIS
( after Horberg )
Contour interval 50 feet; datum sea-level

FIG. 2

On the more steeply dipping west side of the LaSalle anticlinal belt—on the Tuscola dome in southern Champaign and northern Douglas counties—data from studies of wells indicate that Pennsylvanian strata overlapped the Mississippian formations to rest directly on Devonian strata; therefore no Mississippian formations are mapped at the bedrock surface exposed on the west side of the Tuscola dome. A similar overlap seems to exist for the Devonian exposures on the Gibson City dome in northern Champaign and southern Ford counties; hence Pennsyl-




STRUCTURE of TOP of DEVONIAN LIMESTONE and DRAINAGE PATTERN of the BEDROCK SURFACE

◦ Wells to bedrock — Drainage lines — Contour interval 100 feet; datum sea-level

FIG. 3

vanian strata are mapped as lying directly on the Devonian in this area. The Sellers dome on the Oakland anticlinal belt, in central Champaign County, slightly east of the main axis of the LaSalle anticlinal belt, brings Mississippian strata to the bedrock surface.

The New Albany shale is included in the Devonian system in drawing

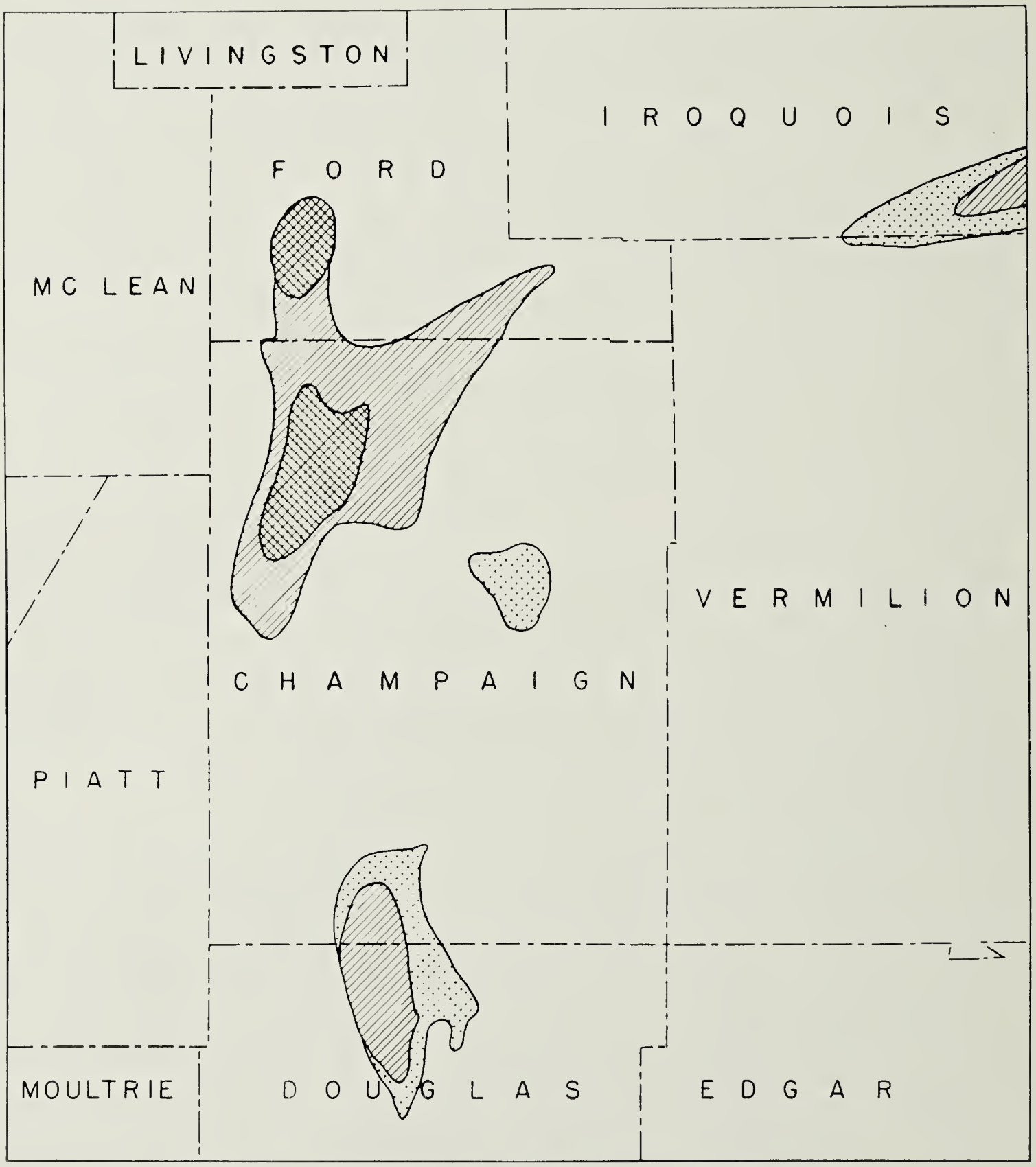



FIG. 4

the areal geologic map of the area. The areal pattern (fig. 4) shows the limits of the Silurian, Devonian, and Mississippian systems, none of which crop out at the surface of the described region. Pennsylvanian strata cover the rest of the area of the bedrock surface, and they crop out in southern Vermilion and northern Edgar counties.

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# PENNSYLVANIAN INSECTS OF ILLINOIS

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The 139 described species of Pennsylvanian insects known from Illinois have come from three rather widely separated areas. One species is known from Colchester, McDonough County; five from Vermilion County, south of Danville; and the rest from Grundy and Will counties, near Braidwood and Coal City, including the famous Mazon Creek locality.

The Francis Creek shale, lying above the Colchester (Wilmington) coal, is exposed naturally on the banks of Mazon Creek in Grundy County and artificially in excavations for coal in adjacent Will County. In both exposures the shale contains nodules formed around fossils. As almost every nodule broken open contains a well-preserved fossil, collecting has been extensive for nearly a century, and the locality has become world-famous for its rich Pennsylvanian flora.

The number of fossil invertebrates associated with the fossil plants is relatively small; few of these are insects. Thus, a season's collecting of fossil plants for the Chicago Natural History Museum usually produces one to three fossil insects; probably as many more disappear into the private collections of a host of enthusiastic amateurs, where they are occasionally examined by members of the Museum staff. As a result of many years of collecting, a small but rather good collection of Pennsylvanian insects now awaits description at the Museum. The present note is intended as an introduction to the work now being done on that collection, and as a brief review of past studies.

The first two species of Pennsylvanian insects to be described from the Mazon Creek nodules were made known in 1864 by James Dwight Dana, the great Yale naturalist. Samuel H. Scudder, of the Boston Society of Natural History and the United States Geological Survey, described 36 more, including the one from Colchester and one from the Danville area. Dana and Scudder may be thought of as representing a "Primitive Period" of fossil insect work in Illinois, which closed about 1905. The extinct orders were not then understood; fossils were assigned to broadly conceived modern orders and were compared with modern genera, or were placed in artificial groups in the belief that insect orders had not become differentiated by Pennsylvanian time.*

The "Middle Period" of Illinois paleoentomology, to pursue the figure, is dominated by Anton Handlirsch, of the Royal Imperial Museum of Vienna. From 1906 to 1920, Handlirsch described 77 species, almost all from Mazon Creek. Being

* "There existed among these ancient forms no ordinal distinctions, such as obtain today, but . . . they formed a single homogeneous group of generalized hexapods, which should be separated from later types more by the lack of those special characteristics which are the property of existing orders than by any definite peculiarities of its own."—Scudder, U. S. Geol. Survey, Bull. 31, p. 104, 1886.

familiar with insects of similar age from Europe, Handlirsch had a better insight than had Dana or Scudder into the problem of a natural classification. He named five new orders for the Pennsylvanian insects and redefined others, giving the classification of paleozoic insects a position of equal stature with that of modern insects. His observations and his taxonomy have not withstood all later tests, but his papers are still a necessary starting point for anyone working with Mazon Creek insects.

Balancing the Primitive and the Middle Periods there is inevitably a Modern Period, in which we hope that all problems will be solved. After Handlirsch's major work, the study of paleozoic insects received a great impetus from the work done by R. J. Tillyard, A. V. Martynov, and F. M. Carpenter on the Permian insects of Australia, Russia, and Kansas. Attention was for a time turned away from Illinois fossils, partly because Handlirsch had studied all the accumulated specimens and new finds were scarce, and partly because of preoccupation with the Permian faunas. Illinois paleoentomology blossomed again in 1938 and 1943 with two papers by Professor F. M. Carpenter, of Harvard University, in which six species are described in terms of the current understanding of venational homologies.

The size of the Pennsylvanian insect fauna of Illinois cannot at present be estimated. Of the 139 known species, some have already been rejected as unrecognizable; others, particularly in the well-stocked genera, may very well sink into synonymy as intermediate forms are found and morphologic variability becomes better understood. The new specimens discovered in current collecting very rarely include representatives of described species, and seldom of described genera; thus the available sample is not yet of significant size.

Pennsylvanian insects are rare fossils. It is desirable that anyone having a specimen in a private collection should lend it to a responsible institution for study, and should arrange for it to go ultimately to a permanent collection. Plaster or Parlodion replicas may be made of these rare specimens, and photographs taken; these can be studied even though the actual specimens remain in personal custody of the collector.

## Checklist of Pennsylvanian Insects Described to 1953 From Illinois

In the following list, no attempt is made at reforming the classification, except in combining Handlirsch's order Protoblattoidea with his order Protorthoptera.

ORDER PALAEODICTYOPTERA

Family Aenigmatodidae Handlirsch 1906

*Aenigmatodes* Handlirsch 1906

*A. danielsi* Handlirsch 1906, Mazon Creek

Family Dictyoneuridae Handlirsch 1906

*Athymodictya* Handlirsch 1911

*A. parva* Handlirsch 1911, Mazon Creek

*Mammia* Handlirsch 1906

*M. alutacea* Handlirsch 1906, Mazon Creek

Family Eubleptidae Handlirsch 1906

*Eubleptus* Handlirsch 1906

*E. danielsi* Handlirsch 1906, Mazon Creek

Family Hypermegethidae Handlirsch 1906

*Hypermegethes* Handlirsch 1906
*H. schuchcrti* Handlirsch 1906, Mazon Creek
Family Syntonopteridae Handlirsch 1911
*Lithoneura* Carpenter 1938
*L. lameerei* Carpenter 1938, Braidwood, Will Co.
*L. mirifica* Carpenter 1943, Braidwood, Will Co.
*Syntonoptera* Handlirsch 1911
*S. schucherti* Handlirsch 1911, Mazon Creek & Braidwood, Will Co.
Family Thesoneuridae Carpenter 1943
*Thesoneura* Carpenter 1943
*T. americana* Carpenter 1943, Braidwood, Will Co.
Family uncertain
*Ametretus* Handlirsch 1911
*A. laevis* Handlirsch 1911, Mazon Creek
*Amousus* Handlirsch 1911
*A. mazonus* Handlirsch 1911, Mazon Creek
*Diexodus* Handlirsch 1911
*D. debilis* Handlirsch 1911, Mazon Creek
*Palaiotaptus* Handlirsch 1906
*P. mazonus* Handlirsch 1906, Mazon Creek
*Parapaolia* Handlirsch 1906
*P. superba* (Scudder 1885, as *Paolia*), Mazon Creek
*Scepasma* Handlirsch 1911
*S. gigas* Handlirsch 1911, Mazon Creek
(supposed larval forms), Mazon Creek & Braidwood, Will Co.

ORDER HADENTOMOIDEA Handlirsch 1906

Family Hadentomidae Handlirsch 1906
*Hadentomum* Handlirsch 1906
*H. americanum* Handlirsch 1906, Mazon Creek

ORDER PROTORTHOPTERA Handlirsch 1906

Family Adeloneuridae Carpenter 1938
*Adcloneura* Carpenter 1938
*A. thompsoni* Carpenter 1938, Mazon Creek
Family Adiphlebiidae Handlirsch 1906
*Adiphlebia* Scudder 1885
*A. lacoana* Scudder 1885, Mazon Creek
*A. longitudinalis* (Scudder 1885, as *Termes*), Mazon Creek
Family Aethophlebiidae Handlirsch 1906
*Acthophlebia* Scudder 1885
*A. singularis* Scudder 1885, Mazon Creek
Family Anthracothremmidae Handlirsch 1906
*Anthracothremma* Scudder 1885
*A. robusta* Scudder 1885, Mazon Creek
*Pericalyphe* Handlirsch 1911
*P. longa* Handlirsch 1911, Mazon Creek
*Melinophlebia* Handlirsch 1911
*M. analis* Handlirsch 1911, Mazon Creek
*Silphion* Handlirsch 1911
*S. latipenne* Handlirsch 1911, Mazon Creek
Family Apithanidae Handlirsch 1911
*Apithanus* Handlirsch 1911
*A. jocularis* Handlirsch 1911, Mazon Creek
Family Asyncritidae Handlirsch 1911
*Asyncritus* Handlirsch 1911
*A. reticulatus* Handlirsch 1911, Mazon Creek
Family Cacurgidae Handlirsch 1911
*Archaeologus* Handlirsch 1906
*A. falcatus* Handlirsch 1906, Mazon Creek
*Cacurgus* Handlirsch 1911
*C. spilopterus* Handlirsch 1911, Mazon Creek
*Heterologus* Carpenter 1943
*H. langfordorum* Carpenter 1943, Braidwood, Will Co.
*Spilomastax* Handlirsch 1911
*S. oligoneurus* Handlirsch 1911, Mazon Creek
Family Cheliphlebiidae Handlirsch 1906
*Cheliphlebia* Scudder 1885
*C. carbonaria* Scudder 1885, Mazon Creek
*C? mazona* Handlirsch 1911, Mazon Creek
*Megalometer* Handlirsch 1906 (family doubtful)
*M. lata* Handlirsch 1906, Mazon Creek
Family Epideigmatidae Handlirsch 1911
*Epideigma* Handlirsch 1911
*E. elegans* Handlirsch 1911, Mazon Creek
Family Eoblattidae Handlirsch 1906
*Anegertus* Handlirsch 1911
*A. cubitalis* Handlirsch 1911, Mazon Creek
Family Encaenidae Handlirsch 1906
*Eucaenus* Scudder 1885
*E. attenuatus* Melander 1903, Mazon Creek
*E. mazonus* Melander 1903, Mazon Creek

*E. minor* Handlirsch 1911, Mazon Creek
*E. ovalis* Scudder 1885, Mazon Creek
*E. pusillus* Handlirsch 1911, Mazon Creek
*E. rotundatus* Handlirsch 1906, Mazon Creek

Family Gerapompidae Handlirsch 1906
*Gerapompus* Scudder 1885
*G. blattinoides* Scudder 1885, Mazon Creek
*G. extensus* Scudder 1885, Mazon Creek
*G. schucherti* Handlirsch 1906, Mazon Creek

Family Geraridae Handlirsch 1906
*Gerarus* Scudder 1885
*G. angustus* Handlirsch 1906, Mazon Creek
*G. collaris* Handlirsch 1911, Mazon Creek
*G. danielsi* Handlirsch 1906, Mazon Creek
*G. latus* Handlirsch 1911, Mazon Creek
*G. longicollis* Handlirsch 1911, Mazon Creek
*G. longus* Handlirsch 1906, Mazon Creek
*G. mazonus* Scudder 1885, Mazon Creek
*G? reductus* Handlirsch 1911, Mazon Creek
*G. vetus* Scudder 1885, Mazon Creek
*Genopteryx* Scudder 1885
*G. constricta* Scudder 1885, Mazon Creek
*Gerarulus* Handlirsch 1911
*G. radialis* Handlirsch 1911, Mazon Creek
*Anepitedius* Handlirsch 1911 (family doubtful)
*A. giraffa* Handlirsch 1911, Mazon Creek

Family Narkemidae Handlirsch 1911
*Narkema* Handlirsch 1911
*N. taeniatum* Handlirsch 1911, Mazon Creek

Family Oedischiidae Handlirsch 1906
*Genentomum* Scudder 1885
*G. validum* Scudder 1885, Mazon Creek
*G. carri* Cockerell 1917, Mazon Creek
*Progenentomum* Handlirsch 1906
*P. carbonis* Handlirsch 1906, Mazon Creek

Family Oryctoblattinidae Handlirsch 1906
*Glaphyrophlebia* Handlirsch 1906
*G. pusilla* Handlirsch 1906, Braceville, Grundy Co.

Family Pachytylopsidae Handlirsch 1906
*Palaeocarria* Cockerell 1917
*P. ornata* Cockerell 1917, Mazon Creek

Family Schuchertiellidae Handlirsch 1911
*Schuchertiella* Handlirsch 1911
*S. gracilis* Handlirsch 1911, Mazon Creek

Family Spanioderidae Handlirsch 1906
*Spaniodera* Handlirsch 1906
*S. acutipennis* Handlirsch 1911, Mazon Creek
*S. ambulans* Handlirsch 1906, Mazon Creek
*S. angusta* Handlirsch 1911, Mazon Creek
*S. elatior* Handlirsch 1911, Mazon Creek
*S. lata* Handlirsch 1911, Mazon Creek
*S. longicollis* Handlirsch 1911, Mazon Creek
*S. parvula* Handlirsch 1911, Mazon Creek
*S. schucherti* Handlirsch 1911, Mazon Creek
*Danielsiella* Cockerell 1916 (*Spaniodera?*)
*D. piscicula* Cockerell 1916, Mazon Creek
*Propteticus* Scudder 1885
*P. infernus* Scudder 1885, Vermilion Co.
*Camptophlebia* Handlirsch 1906
*C. clarinervis* (Melander 1903, as *Dictyoneura*), Vermilion Co.
*Paracheliphlebia* Handlirsch 1906
*P. extensa* (Melander 1903, as *Cheliphlebia*), Mazon Creek
*Petromartus* Melander 1903 (family doubtful)
*P. indistinctus* Melander 1903, Vermilion Co.
*Miamia* Dana 1864 (family doubtful)
*M. bronsoni* Dana 1864, Mazon Creek
*Gyrophlebia* Handlirsch 1906
*G. longicollis* Handlirsch 1906, Mazon Creek
*Metacheliphlebia* Handlirsch 1906 (family doubtful)
*M. elongata* (Scudder 1885 as *Cheliphlebia*), Mazon Creek
*Dieconeura* Scudder 1885
*D. arcuata* Scudder 1885, Mazon Creek

*D. mazona* Handlirsch 1911, Mazon Creek
*Metryia* Handlirsch 1906
*M. analis* Handlirsch 1906, Mazon Creek
Family uncertain
*Agogoblattina* Handlirsch 1906
*A. occidua* (Scudder 1885, *Oryctoblattina*), Mazon Creek
*Axiologus* Handlirsch 1906
*A. thoracicus* Handlirsch 1906, Mazon Creek
*Chrestotella* Handlirsch 1919
*C. danae* (Scudder 1868, *Miamia*), Mazon Creek
*Chrestotes* Scudder 1868
*C. lapidea* Scudder 1868, Mazon Creek
*Didymophleps* Scudder 1885
*D. contusa* (Scudder 1878, as *Termes*), Vermilion Co.
*Endoiasmus* Handlirsch 1906
*E. reticulatus* Handlirsch 1906, Mazon Creek
*Geraroides* Handlirsch 1906
*G. maximus* (Melander 1903, as *Dieconeura*), Mazon Creek
*Hemeristia* Dana 1864
*H. occidentalis* Dana 1864, Mazon Creek
*Polyernus* Scudder 1885
*P. complanatus* Scudder 1885, Mazon Creek
*Polyetes* Handlirsch 1906
*P. furcifer* Handlirsch 1906, Mazon Creek
*Pseudogerarus* Handlirsch 1906
*P. scudderi* Handlirsch 1906, Mazon Creek
(larval forms), Mazon Creek

ORDER BLATTARIA

Family Archimylacridae Handlirsch 1906
*Adeloblatta* Handlirsch 1906
*A. columbiana* (Scudder 1895, as *Progonoblattina*), Mazon Creek
*A. sellardsi* (Handlirsch 1906, as *Phylloblatta*), Mazon Creek
*Archoblattina* Sellards 1904
*A. beecheri* (Sellards 1903, as *Megablattina*), Mazon Creek
*A. scuddcri* Handlirsch 1906 (syn. of *bcechcri?*), Mazon Creek
*Asemoblatta* Handlirsch 1906
*A. danielsi* Handlirsch 1906, Mazon Creek
*A. mazona* (Scudder 1882, as *Etoblattina*), Mazon Creek
*Metachorus* Handlirsch 1920 (family questionable)
*M. testudo* (Scudder 1890, as *Promylacris*), Mazon Creek
*Oxynoblatta* Handlirsch 1906
*O? triangularis* (Scudder 1895, as *Paromylacris*), Mazon Creek
*Palaeoblatta* Handlirsch 1906
*P. paucinervis* (Scudder 1890, as *Archimylacris*), Mazon Creek
*Phyloblatta* Handlirsch 1906 (often spelled *Phylloblatta*)
*P. diversipennis* Handlirsch 1911, Mazon Creek
*P. hilliana* (Scudder 1895, as *Etoblattina*), Mazon Creek
Archimylacrid larvae
*Dipeltis* (*Diplodiscus*) *carri* Schuchert 1897, Mazon Creek
*Etoblattina mazonana* Sellards 1904, Mazon Creek
...*larvalis* Handlirsch 1920, Mazon Creek
...*paidium* Handlirsch 1920, Mazon Creek
Family Mylacridae Scudder 1885
*Mylacris* Scudder 1868
*M. anthracophila* Scudder 1868, Colchester, McDonough Co.
*M. elongata* Scudder 1895, Mazon Creek
*M. similis* Handlirsch 1906, Mazon Creek
*M. sellardsii* Handlirsch 1906, Mazon Creek
*M. ampla* Scudder 1895, Mazon Creek
*Orthomylacris* Handlirsch 1906
*O. antiqua* (Scudder 1884, as *Mylacris*), Mazon Creek
*O. contorta* Handlirsch 1911, Mazon Creek
*O. gurleyi* (Scudder 1895, as *Mylacris*), Mazon Creek
*O. rigida* (Scudder 1890, as *Promylacris*), Mazon Creek
*Paromylacris* Scudder 1885
*P. rotunda* Scudder 1885, Mazon Creek
*Platymylacris* Handlirsch 1911
*P. paucincrvis* Handlirsch 1911, Mazon Creek
*Promylacris* Scudder 1885
*P. ovalis* Scudder 1885, Mazon Creek
*Simplicius* Handlirsch 1920
*S. simplex* (Scudder 1879, as *Lithomylacris*), Danville area, Vermilion Co.
mylacrids of uncertain genus
...*ampla* Scudder 1890 (as *Paromylacris*), Mazon Creek

...*amplipennis* Handlirsch 1920, Mazon Creek
mylacrid larvae
...*sellardsii* Handlirsch 1906, Mazon Creek
...*melanderi* Handlirsch 1906, Mazon Creek
...*schuchertiana* Handlirsch 1906, Mazon Creek
...*sellardsiana* Handlirsch 1906, Mazon Creek
...*diplodiscus* Packard 1885 (as *Dipeltis*), Mazon Creek
...*anceps* Sellards 1904, Mazon Creek

ORDER SYPHARAOPTEROIDEA Handlirsch 1911
Family Sypharopteridae Handlirsch 1911
*Sypharoptera* Handlirsch 1911
*S. pneuma* Handlirsch 1911, Mazon Creek

ORDER PROTODONATA
Family Paralogidae Handlirsch 1906
*Paralogopsis* Handlirsch 1911
*P. longipes* Handlirsch 1911, Mazon Creek

ORDER MEGASECOPTERA
Family Prochoropteridae Handlirsch 1911
*Prochoroptera* Handlirsch 1911
*P. calopteryx* Handlirsch 1911, Mazon Creek
Family uncertain
*Adiaphtharsia* Handlirsch 1906
*A. ferrea* Handlirsch 1906, Mazon Creek
*Lameereites* Handlirsch 1911
*L. curvipennis* Handlirsch 1911 (doubtful form), Mazon Creek

ORDER UNCERTAIN
*Teneopteron* Carpenter 1943
*T. mirabile* Carpenter 1943, Braidwood area, Will Co.
*Megathenthomum* Scudder 1868
*M. pustulatum* Scudder 1868, Mazon Creek
*M. scudderi* Handlirsch 1906, Mazon Creek
*Protodictyon* Melander 1903
*P. pulchripenne* Melander 1903, Mazon Creek
*Geraropsis* Handlirsch 1919
*G. scudderi* Handlirsch 1919, Mazon Creek

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# PROSPECTING FOR COMMERCIAL SAND AND GRAVEL USING ELECTRICAL EARTH RESISTIVITY, CLINTON COUNTY, ILLINOIS*

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*State Geological Survey, Urbana*

Electrical earth-resistivity methods for locating deposits of water-bearing sand and gravel have been used by the Illinois State Geological Survey for many years. The methods used in interpreting resistivity data have been largely empirical but nevertheless very successful for locating large deposits of water-bearing sand and gravel suitable for municipal and industrial water supplies. These empirical interpretations have been based on methods outlined by O. H. Gish and W. J. Rooney[1] using the Gish-Rooney curve, the Moore cumulative curve outlined by R. Woodward Moore,[2] and the resistivity profile outlined by K. O. Emery.[3]

The sand and gravel deposits located by these empirical resistivity methods have usually been relatively large, fairly clean deposits associated with glacial till, made up largely of clays and silts. Resistivity of sand or gravel is generally 200 to 300 times as great as that of the surrounding glacial till, which permits successful use of empirical methods of interpretation. Experience has shown that, when the lithology of an area does not give a sharp contrast in resistivities, accurate interpretation is difficult.

In an attempt to interpret complex geological areas more accurately, the Division of Groundwater Geology and Geophysical Exploration of the Illinois State Geological Survey inaugurated a research program to investigate the application of other methods of analyzing resistivity data. The literature on interpretation of electrical earth resistivity data was studied intensively and a report was prepared outlining the methods advanced by G. F. Tagg,[4] William A. Longacre,[5] Sylvain J. Pirson,[6] Irwin Roman,[7] Robert J. Watson and James F. Johnson,[8] W. W. Wetzel and Howard V. McMurry,[9] R. Woodward Moore,[10] I. E. Rosenzweig,[11] and R. J. Wat-

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[1] Gish, O. H. and Rooney, W. J., Measurement of resistivity of large masses of undisturbed earth: Terr. Mag., vol. 30, pp. 161-188, 1925.

[2] Moore, R. Woodward, An empirical method of interpretation of earth-resistivity measurement: AIME Trans. Geophysics, vol. 164, p. 197, 1945.

[3] Emery, K. O., Electrical earth resistivity survey at Peoria and vicinity: Unpublished report, Illinois Geological Survey, 1941.

[4] Tagg, G. F., Interpretation of resistivity measurements: AIME Geophysical Prospecting, vol. 110, pp. 135-145, 1934.

[5] Longacre, William A., A study of the problem of depth determination by means of earth-resistivity measurements: AIME Trans. Geophysics, vol. 164, pp. 179-185, 1945.

[6] Pirson, Sylvain J., Interpretation of three layer resistivity curves: AIME Geophysical Prospecting, vol. 110, pp. 148-158, 1934.

[7] Roman, Irwin, Some interpretations of earth-resistivity data: AIME Geophysical Prospecting, vol. 110, pp. 183-197, 1934.

[8] Watson, R. J. and Johnson, J. F., On the extension of two-layer methods of interpretation of earth-resistivity data to three and more layers: Geophysics, vol. 3, pp. 7-21, 1938.

[9] Wetzel, W. W. and McMurry, H. V., A set of curves to assist in the interpretation of the three-layer resistivity problem: Geophysics, vol. 11, no. 4, pp. 329-341, 1937.

[10] Moore, R. Woodward, An empirical method of interpretation of earth-resistivity measurements: AIME Trans. Geophysics, vol. 164, p. 197, 1945.

[11] Rosenzweig, I. E., A new method of depth determination in earth-resistivity measurements: AIME Geophysical Prospecting, vol. 138, pp. 408-417, 1940.

son.[12] The method described by Wetzel and McMurry seemed to be the most promising.

Locating deposits of sand or gravel for commercial use is one of the major problems that are often associated with a complex geologic situation. Such a problem arose when the Clinton County Highway Department requested information from the Survey on prospecting areas for sand and gravel to be used for road building. In order to locate areas worth testing by drilling, an electrical earth resistivity survey was conducted. The area investigated included Irishtown and Wheatfield townships, Clinton County, which lie between the Kaskaskia River on the east and Shoal Creek on the west, and which are bounded on the north by the Clinton-Bond county line. A few stations were also located in Wade township. The entire area was in townships 2 and 3 north, ranges 2 and 3 west.

The major portion of the area is relatively flat upland prairie that stands about 470 feet above sea level. The general flatness is relieved by morainic hills that rise sharply to a height of more than 40 feet and form impressive features of the landscape. There are many of these hills along the Clinton-Bond county line and in the northeast portion of Irishtown township around Keysport. The hills are of three distinct forms, rounded, elongated, and irregular. The principal drainage of the area is the Kaskaskia River and its tributaries, among which are Beaver Creek and Shoal Creek. On the whole the area between the Kaskaskia River and Beaver Creek is poorly drained. The gradient of the Kaskaskia River is about one foot per mile.

Several criteria governed the field work for the resistivity survey. Since the sand or gravel was to be used as road-building material, the deposits had to be at relatively shallow depths to be economically feasible to develop. Therefore, the investigation was limited to depths of less than fifty feet. As it seemed likely that the best deposits would be in the morainic hills, stations on and around the hills were located about a tenth of a mile apart. Stations on the flat prairie were located about two-tenths of a mile apart. They were generally placed along roads, but a few were located in fields (see fig. 1).

The data were plotted on 2 x 2 cycle logarithm paper and interpreted by superposing the curves obtained from field data over master curves as outlined by W. W. Wetzel and Howard V. McMurry.[13] This method applies to the three-layer case in which the thickness of the top layer is ($h_1$), the thickness of the second layer is (d), the thickness of the third layer is infinite, the depth from the surface to the top of the third layer is ($h_2$), and the resistivities of the layers are $\rho_1$, $\rho_2$, and $\rho_3$, respectively. The following values are determined from the master curves: ($h_2$), depth to top of third layer; ($\rho_1$), resistivity of top layer; ($h_1$:d), ratio of thickness of first and second layers.

The readings from each station were plotted, and an attempt was made to interpret each curve. How-

[12] Watson, R. J., A contribution to the theory of the interpretation of resistivity measurements obtained from surface potential observations: AIME Geophysical Prospecting, vol. 110, pp. 201-232, 1934.

[13] Wetzel, W. W. and McMurry, H. V., op. cit.

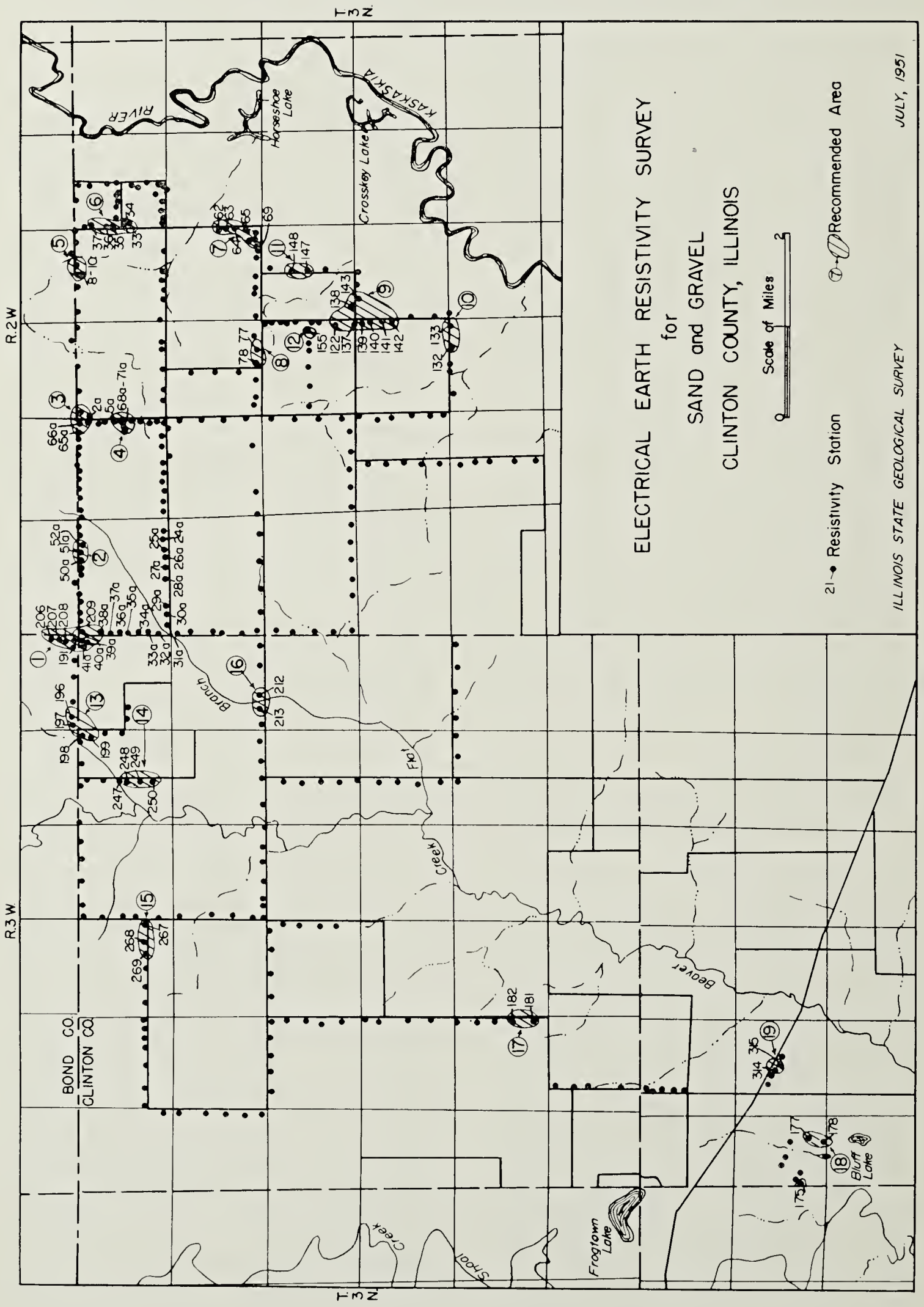
ELECTRICAL EARTH RESISTIVITY SURVEY
for
SAND and GRAVEL
CLINTON COUNTY, ILLINOIS
Scale of Miles
0
2
21 Resistivity Station
Recommended Area
ILLINOIS STATE GEOLOGICAL SURVEY
JULY, 1951
R.2W
R.3W
T. 3 N
T. 3 N
BOND CO.
CLINTON CO.
Horseshoe Lake
Crossley Lake
KASKASKIA RIVER
Frogtown Lake
Blue Lake
Beaver Creek
Shoal Creek
Fox Creek
Branch

FIG. 1

ever, many of the curves did not lend themselves to very good interpretations because the plotted points did not conform to a typical three-layer situation. The stations that did lend themselves most readily to interpretations are listed in groups in table 1. The areas listed in table 1 were recommended for prospecting with particular emphasis on areas 1, 2, 7, 9, and 18.

The areas recommended for prospecting were selected on the basis of several considerations. The first consideration was that of the class of master curves to which the data conformed. The governing criterion was the ratio of resistivities. It was reasoned that, in this survey, sand or gravel deposits would be surrounded by glacial till with the resistivity of the till relatively low and the resistivity of the sand or gravel relatively high. The magnitude of the resistivity of the sand or gravel would depend upon the degree of silt and other impurities included. It was thought that a desirable curve would be one in which the ratio of resistivities ($\rho_1 : \rho_2 : \rho_3$) was in the order of 1:100:1.

The second consideration was to select areas in which resistivity stations close together fell into one class of master curves. It was felt that the more stations in a given area that had the same type of master curve, the greater was the possibility of finding a deposit large enough to be developed commercially.

The third consideration was that of the range and magnitude of the apparent resistivity readings ($\rho_a$) at a particular station. As clean sand or gravel should have a high resistivity, stations where the resistivity values ranged from low to relatively high readings were considered to be good possibilities. An example of this is station 39a in prospecting area 1, where resistivities ranged from 8400 ohm-centimeters to 40,000 ohm-centimeters (see table 1). Using the information in table 1, a Clinton County Highway Department crew test-drilled some of the recommended locations. A representative of the Illinois State Geological Survey accompanied the drilling crew and collected samples. The test-drilling was somewhat inadequate because the available equipment was only able to penetrate to 20 feet. Sixteen test holes were drilled and in 13 of the 16 there were good correlations between the actual records and the predictions based on resistivity interpretations. Table 2 shows the test hole data compared with the resistivity interpretations.

## Analysis of Data

In table 1 estimates of the thickness of the top layer ($h_1$) and the second layer (d) are given. These were computed algebraically from the information obtained from the master curves based on the contact depth ($h_2$). It can be seen in table 2 that the most accurately interpreted value was ($h_2$), the depth to the top of the third layer.

*Station 39a.*—The resistivity ratio here is $\rho_1 : \rho_2 : \rho_3 = 1:100:1$, which indicates the resistivity of the second layer to be relatively large. Resistivity readings ($\rho_a$) range from 8400 ohm-cms. to 40,000 ohm-cms. In this case there is a correlation between ($h_1$), estimated at 12 feet, and the first lithologic break, which the test hole showed to be at 14 feet. The interpretation of ($h_2$) is also believed to be valid as the total depth of the test hole is only 20 feet. The resistivity ratio is consistent with the

TABLE 1.—INTERPRETATION OF ELECTRICAL EARTH RESISTIVITY DATA IN AREAS RECOMMENDED FOR PROSPECTING FOR SAND OR GRAVEL

| *Area no.* | *Station no.* | *Resistivity ratio* $\rho_1 : \rho_2 : \rho_3$ | *Estimated contact depth* ($h_2$) | *Estimated overburden* ($h_1$) | *Estimated thickness of sand/gravel* (d) | *Range of resistivity readings* ($\rho_a$) ohm-cm |
|---|---|---|---|---|---|---|
| 1 | 38a | 1:10 :1 | 19 | 14 | 5 | 6900-14000 |
| | 39a | 1:100:1 | 24 | 12 | 12 | 8400-40000 |
| | 40a | 1:100:1 | 34 | 17 | 17 | 4300-17200 |
| | 41a | 1:100:1 | 21 | 10 | 11 | 5000-31800 |
| | 209 | 1:10 :1 | 28 | 14 | 14 | 5000-15400 |
| | 208 | 1:10 :3 | 30 | 15 | 15 | 7100-22800 |
| | 206 | 1:10 :⅓ | 28 | 7 | 21 | 10100-31300 |
| | 191 | 1:100:1 | 11 | 8 | 3 | 7000-26500 |
| 2 | 50a | 1:10 :1 | 13 | 3 | 10 | 3000-16700 |
| | 51a | 1:10 :1 | 13 | 4 | 9 | 2700-16600 |
| | 52a | 1:10 :⅓ | 27 | 7 | 20 | 3500-9400 |
| 3 | 65a | 1:100:⅓ | 16 | 12 | 4 | 3900-15300 |
| | 66a | 1:10 :3 | 9 | 6 | 3 | 4100-14500 |
| | 1a | 1:10 :3 | 12 | 9 | 3 | 6300-19300 |
| | 2a | 1:10 :1 | 21 | 15 | 6 | 4800-12800 |
| | 1 | 1:10 :3 | 13 | 7 | 6 | 3300-10000 |
| 4 | 5a | 1:10 :⅓ | 20 | 10 | 10 | 5500-11100 |
| | 68a | 1:10 :3 | 10 | 7 | 3 | 6500-20800 |
| | 69a | 1:100:10 | 22 | 16 | 6 | 7300-27500 |
| | 70a | 1:100:1 | 18 | 14 | 4 | 8600-26700 |
| | 71a | 1:10 :⅓ | 13 | 7 | 6 | 4400-6800 |
| 5 | 8 | 1:10 :3 | 8 | 6 | 2 | 6600-16000 |
| | 9 | 1:10 :3 | 11 | 8 | 3 | 5700-20500 |
| | 10 | 1:10 :3 | 6 | 4 | 2 | 5000-19800 |
| | 11 | 1:10 :1/10 | 15 | 8 | 7 | 4500-8000 |
| 6 | 33 | 1:⅓ :3 | 31 | 8 | 23 | 11400-4000 |
| | 34 | 1:10 :3 | 19 | 14 | 5 | 6800-11000 |
| | 35 | 1:100:1/10 | 14 | 11 | 3 | 6400-21300 |
| | 36 | 1:10 :1 | 34 | 8 | 26 | 6600-21600 |
| | 37 | 1:10 :3 | 18 | 9 | 9 | 4000-13700 |
| 7 | 62 | 1: 3 :100 | 20 | 20 | ? | 5000-25000 |
| | 63 | 1:100:1 | 33 | 16 | 17 | 7000-24000 |
| | 64 | 1:10 :100 | 15 | 11 | 4 | 3500-18000 |
| | 65 | 1:10 :3 | 13 | 7 | 6 | 3000-9200 |
| | 69 | 1:100:1 | 22 | 16 | 6 | 4000-12400 |
| 8 | 77 | 1:10 :3 | 8 | 6 | 2 | 5000-12800 |
| | 78 | 1:10 :1/10 | 30 | 15 | 15 | 3000-6000 |
| 9 | 142 | 1:10 :3 | 12 | 9 | 3 | 5000-16700 |
| | 141 | 1: 3 :10 | 9 | 6 | 3 | 4000-20000 |
| | 140 | 1:10 :1 | 20 | 10 | 10 | 4300-9600 |
| | 139 | 1:10 :1 | 15 | 10 | 5 | 4100:9900 |
| | 137 | 1:10 :⅓ | 27 | 13 | 14 | 5600-11900 |
| | 122 | 1:10 :⅓ | 25 | 12 | 13 | 3300-9200 |
| | 138 | 1:100:⅓ | 10 | 7 | 3 | 3900-15000 |
| | 143 | 1:1/9:∞ | 35 | 35 | ? | 9400-1800 |

TABLE 1.—(CONTINUED)

| *Area no.* | *Station no.* | *Resistivity ratio* $\rho_1 : \rho_2 : \rho_3$ | *Estimated contact depth* ($h_2$) | *Estimated overburden* ($h_1$) | *Estimated thickness of sand/gravel* (d) | *Range of resistivity readings* ($\rho_a$) ohm-cm |
|---|---|---|---|---|---|---|
| 10 | 132 | 1:1/10:100 | 16 | 16 | ? | 5300-1500 |
| | 133 | 1:1/5.67:∞ | 8 | 8 | ? | 10300-3900 |
| 11 | 147 | 1:1/10:3 | 10 | 10 | ? | 5800-3100 |
| | 148 | 1:10 :1 | 25 | 12 | 13 | 5900-13200 |
| 12 | 155 | 1:10 :1 | 15 | 7 | 8 | 3800-10200 |
| 13 | 196 | 1:10 :3 | 12 | 9 | 3 | 3600-10500 |
| | 197 | 1:10 :3 | 10 | 7 | 3 | 4200-10700 |
| | 198 | 1:19 :2.11 | 31 | 15 | 16 | 2500-8000 |
| | 199 | 1:10 :1/10 | 21 | 15 | 6 | 1900-4300 |
| 14 | 247 | 1:10 :3 | 24 | 12 | 12 | 4700-13700 |
| | 248 | 1:100:1 | 16 | 12 | 4 | 4300-22000 |
| | 249 | 1: 3 :1 | 28 | 7 | 21 | 5000-10700 |
| 15 | 267 | 1:⅓:10 | 15 | 15 | ? | 4300-6600 |
| | 269 | 1:⅓:1 | 15 | 15 | ? | 7800-5300 |
| 16 | 212 | 1:100:⅓ | 14 | 10 | 4 | 1400-5000 |
| | 213 | 1:100:1 | 24 | 18 | 6 | 3000-6200 |
| 17 | 181 | 1:10 :3 | 17 | 8 | 9 | 2300-7800 |
| | 182 | 1:10 :3 | 10 | 7 | 3 | 2900-8000 |
| 18 | 175 | 1:10:1/100 | 17 | 8 | 9 | 2500-5500 |
| | 177 | 1:10:1 | 16 | 4 | 12 | 3000-11200 |
| | 178 | 1: 3:10 | 12 | 6 | 6 | 3300-14300 |
| 19 | 314 | 1:100:1 | 7 | 5 | 2 | 4400-15900 |
| | 315 | 1:10 :1/10 | 12 | 6 | 6 | 7000-16700 |

lithology because the clean, fine sand below 14 feet would have a high resistivity as compared to the resistivity of silty clay above 14 feet.

*Station 208.*—The resistivity ratio of 1:10:3 indicates that the second layer might be expected to be sand or gravel that is slightly more impure than the second layer material at station 39a. The relative resistivity (3) of the third layer indicates that the resistivity of the top layer is probably lower, and that of the second layer higher. Therefore, the material of the third layer probably has more silt, clay, or impurities than the second layer. This is partially borne out by the test hole logs which show a lithologic break at 14 feet, the top of the second layer. This is consistent with theory, in that, beginning at 14 feet, the stratum changes to a cleaner gravel which has a much higher resistivity than the clayey layer above it. The fairly high resistivity readings, ranging from 7,100 to 22,800 ohm-cms., indicate the possibility of sand or gravel.

*Station 206.*—The resistivity ratio of 1:10:⅓ implies that the second layer is composed of fairly clean sand or gravel, that the top layer possibly contains some sand or gravel, and that the bottom layer is composed of silty or clayey material. The high resistivity readings, from 10,100 to 31,300 ohm-cms., also imply good sand and gravel possibilities. The first 20 feet tested shows clean gravel with pebbles up to two inches in diameter. It is felt that 28 feet as the thickness of the top layer is a good interpretation, although the test hole only went down 20 feet.

TABLE 2.—LOGS OF TEST HOLES AND COMPARISON OF EARTH RESISTIVITY INTERPRETATIONS WITH ACTUAL CONDITIONS

| *Area no.* | *Station no.* | *Test hole logs* | | *Resistivity ratio* $\rho_1 : \rho_2 : \rho_3$ | *Estimated contact depth* ($h_2$) | *Estimated overburden* ($h_1$) | *Estimated thickness of sand or gravel* (d) |
|---|---|---|---|---|---|---|---|
| | | *Depth (ft.)* | *Material* | | | | |
| 1 | 39a | 0-14 | Clay, silty and pebbly, tough, yellow-brown | 1:100:1 | 24* | 12* | 12 |
| | | 14-20 | Sand, clean, fine to medium, reddish | | | | |
| | 208 | 0-8 | Silt, clayey, sandy, pebbly, reddish-brown | 1:10:3 | 30 | 15* | 15 |
| | | 8-14 | Gravel, slightly clayey and sandy, pebbles up to ¾-inch size | | | | |
| | | 14-20 | Same, less clayey | | | | |
| | 206 | 0-20 | Fairly clean gravel up to 2-inch pebbles | 1:10:⅓ | 28* | 7 | 21 |
| | 191 | 0-12 | Silt, sandy, clayey, pebbly, yellowish brown | 1:100:1 | 11* | 8 | 3 |
| | | 12-16 | Same, more sandy, darker | | | | |
| | | 16-20 | Gravel, slightly sandy and silty. Pebbles up to ¾-inch size | | | | |
| 2 | 52a | 0-15 | Silt, clayey, slight sand and pebbles, reddish-brown | 1:10:1 | 13* | 3 | 10 |
| | | 15-20 | Clay, very gravelly, reddish-brown | | | | |
| 4 | 5a | 0-18 | Silt, sandy, pebbly, dry, reddish-brown, gravel at base | 1:10:⅓ | 20* | 10 | 10 |
| | | 18-20 | Sand, clean, fine, reddish-brown | | | | |
| | 68a | 0-12 | Silt, slightly sandy, reddish-brown | 1:10:3 | 10* | 7 | 3 |
| | | 12-20 | Clayey, sandy, pebbly, yellow-brown | | | | |

* Predicted depths that are within two feet of the test hole data.

TABLE 2.—(CONTINUED)

| *Area no.* | *Station no.* | *Test hole logs* | | *Resistivity ratio* $\rho_1 : \rho_2 : \rho_3$ | *Estimated contact depth* ($h_2$) | *Estimated overburden* ($h_1$) | *Estimated thickness of sand or gravel* (d) |
|---|---|---|---|---|---|---|---|
| | | *Depth (ft.)* | *Material* | | | | |
| 6 | 35 | 0-12 | Silt, sandy, clayey, pebbly, yellow-brown | 1:100:1/10 | 14* | 11* | 3* |
| | | 12-14 | Clean sand, reddish brown | | | | |
| | | 14-20 | Clay, tough, silty, pebbly | | | | |
| | 36 | 0-12 | Silt, slightly sandy and pebbly, light brown | 1:10:1 | 34 | 8 | 26 |
| | | 12-20 | Silt, sandy, with gray sheets, yellowish gray at bottom. | | | | |
| 7 | 65 | 0-10 | Silt, sandy, pebbly clayey, reddish-brown | 1:10:3 | 13* | 7 | 6 |
| | | 10-20 | Silt, very sandy | | | | |
| 9 | 140 | 0-12 | Sand, very fine, silty clayey yellowish-brown | 1:10:1 | 20 | 10* | 10 |
| | | 12-20 | Sand, very fine, clean darker brown | | | | |
| 10 | Btwn. 132& 133 | 0-18 | Till, very pebbly, yellowish-brown | 1:1/10:100 | 16* | 16 | ? |
| | | 18-20 | Till less pebbly, more clayey | | | | |
| 18 | 175 | 0-16 | Silt, sandy, clayey, grayish brown | 1:10:1/100 | 17* | 8 | 9 |
| | | 16-20 | Till, very pebbly, reddish brown | | | | |
| | 177 | 0-17 | Sand, silty, clayey, slightly pebbly, reddish brown | 1:10:1 | 16* | 4 | 12 |
| | | 17-20 | Sand, very fine and clean | | | | |
| | 178 | 0-10 | Silt, sandy, clayey, grayish brown | 1:3:10 | 12* | 6 | 6 |
| | | 10-18 | Silt, same pebbly | | | | |
| | | 18-20 | Sand, fine, silty, clayey, reddish brown | | | | |
| 19 | 315 | 0-10 | Sand, fine, slightly clayey and silty, reddish brown | 1:10:1/10 | 12* | 6 | 6 |
| | | 10-20 | Sand, finer, less clayey and silty | | | | |

*Station 191.*—The resistivity ratio of 1:100:1 implies that the top and bottom layers are composed of silty, clayey material and the second layer of fairly clean sand or gravel. The moderately high resistivity readings, ranging from 7,000 to 26,500 ohm-cms., indicate good sand or gravel possibilities. The interpretation shows a break at 11 feet and the test-hole log a break at 12 feet from silty, clayey material to sandier material. It appears here, as well as in most of the remaining stations, that the most significant value that can be determined is ($h_2$), the depth of the contact between sand or gravel of the second layer and silty-clayey material below. The ($h_1$) and (d) values do not seem to be valid.

*Station 52a.*—The resistivity ratio of 1:10:1 implies that the top and bottom layers are composed of silty-clayey material and that the second layer is slightly dirty sand or gravel. The resistivity readings of 3,000 to 16,700 ohm-cms. may be considered medium. The contact depth ($h_2$) was interpreted to be 13 feet, comparing favorably with the test-hole log which indicates a lithologic break, at 15 feet, from silty clayey sand to a very gravelly clay.

*Station 5a.*—The resistivity ratio of 1:10:⅓ implies that the top layer is very dirty sand containing considerable silt and clay grading into the cleaner sand or gravel of the second layer. The third layer is principally silt and clay. The interpretation of ($h_2$) was 20 feet and compares favorably with the test-hole log which shows a break, at 18-20 feet, from sandy silt to a clean, fine, reddish brown sand. The resistivity readings range from 5,500 to 11,100 ohm-cms.

*Station 68a.*—The resistivity ratio of 1:10:3 implies a top layer of silty-clayey material and a second layer of fairly clean sand or gravel grading into a third layer of dirty sand or gravel. The resistivity readings are fairly high, ranging from 6,500 to 20,800 ohm-cms. The contact depth ($h_2$) of 10 feet compares favorably with the test-hole log, which shows a break, at 12 feet, from slightly sandy silt to a clayey, pebbly, yellow-brown sand.

*Station 35.*—The resistivity ratio of 1:100:1/10 implies a somewhat sandy top layer with a second layer of very clean sand or gravel and a very clayey bottom layer. The resistivity readings have a fairly high range, from 6,400 to 21,300 ohm-cms., and indicate good sand or gravel. The interpreted thickness of 11 feet for ($h_1$) compares with the test-hole log which shows a lithologic break at 12 feet from a sandy silt to a clean reddish-brown sand. The contact depth ($h_2$) of 14 feet is also consistent with the test-hole log which shows a lithologic break, at 14 feet, from a clean reddish-brown sand to a tough, silty clay. The theoretical interpretation seems to conform almost exactly to the actual conditions.

*Station 36.*—The resistivity ratio of 1:10:1 implies that the top layer and the bottom layer are composed of silty clay and that the second layer is fairly clean sand or gravel. The resistivity readings have a fairly high range, 6,600 to 21,600 omh-cms., indicating fairly good sand or gravel. Not much can be said about the validity of the interpretation since the test-hole was only 20 feet deep and the interpreted contact depth ($h_2$) was estimated to be at 34 feet. However, the ($h_1$) of 8 feet is reasonably close to the first lithologic break, indicated at 12 feet in the test-hole log.

*Station 65.*—The resistivity ratio of 1:10:3 implies a top layer of silty-clayey material, with a second layer of fairly clean sand or gravel grading into a third layer of rather dirty sand or gravel. The resistivity readings, 3,000 to 9,200 ohm-cms., are not very high and indicate a sand or gravel that is not too clean. The contact depth ($h_2$) of 13 feet corresponds rather favorably to the test-hole log, in which there is a lithologic break, indicated at 10 feet, from a reddish-brown slightly sandy silt to a very sandy silt.

*Station 140.*—The resistivity ratio of 1:10:1 implies that the top layer and the bottom layer are composed of silty clay and that the second layer is a fairly clean sand or gravel. The resistivity readings, 4,300 to 9,600 ohm-cms., are not very high and indicate a sand or gravel that is not too clean. There does not seem to be any correlation between the contact depth ($h_2$) and the test-hole log. There might be correlation if there is a lithologic change at 20 feet, but without drilling a deeper hole there is no way of determining it. However, the ($h_1$) depth of 10 feet does correlate fairly well with the lithologic break at 12 feet in the test-hole log, where the material changes from a fine silty sand to a fine clean sand.

*Station 132.*—The resistivity ratio of 1:1/10:100 implies that the second layer, composed of a silty-clayey material having a low resistivity, is overlain by a material of greater resistivity such as sandy or pebbly till. The bottom layer, having a relative resistivity of 100, should be composed of fairly clean sand or gravel. The resistivity readings range from 5,300 to 1,500 ohm-cms. and then go back up to 5,000 ohm-cms. The reading is not very high and seems to contradict the statement made above that clean sand or gravel might be expected. On the basis of low resistivity readings the possibility of finding good sand or gravel is rather remote. Nevertheless the contact depth ($h_2$) of 16 feet compares favorably with the lithologic break, indicated in the test-hole log at 18 feet, where the material changes from very pebbly till to more clayey till.

*Station 175.*—The resistivity ratio of 1:10:1/100 implies that the second layer is composed of fairly clean sand or gravel, the top layer has some sand, and the bottom layer is tough and clayey. The resistivity readings, 2,500 to 5,500 ohm-cms., are rather low and do not indicate good sand and gravel. The contact depth ($h_2$) of 17 feet compares favorably with the lithologic break, indicated in the test-hole log at 16 feet, where the material changes from a sandy silt to a very pebbly till.

*Station 177.*—The resistivity ratio of 1:10:1 implies that the second layer is composed of fairly clean sand or gravel and the top and bottom layers are composed of silty clay. The resistivity readings, 3,000 to 11,200 ohm-cms., may be considered medium and indicate fairly good sand or gravel. The contact depth ($h_2$) of 16 feet compares favorably with the lithologic break, indicated in the test-hole log at 17 feet, where the material changes from a silty-clayey sand to a very fine and clean sand.

*Station 178.*—The resistivity ratio of 1:3:10 implies that the top layer is composed of silty-clayey material grading into a second layer of dirty sand or gravel, and the third layer is fairly clean sand or gravel. The resistivity readings, 3,300 to 14,300 ohm-cms., may be considered medium and indicate fairly good sand or gravel. The contact depth ($h_2$) of 12 feet compares favorably with the lithologic break, indicated in the test-hole log at 10 feet, where the material changes from a sandy-clayey silt to a pebbly silt.

*Station 315.*—The resistivity ratio of 1:10:1/10 implies that the second layer is composed of fairly clean sand or gravel, the top layer is somewhat sandy, and the bottom layer is silty and clayey. The resistivity readings, 7,000 to 16,700 ohm-cms., may be considered medium and indicate fairly good sand or gravel. The contact depth ($h_2$) of 12 feet compares favorably with the lithologic break, indicated in the test-hole log at 10 feet, changing from a slightly silty-clayey reddish-brown sand to a cleaner, finer sand.

## Summary

The methods of interpreting the resistivity data, as outlined by W. W. Wetzel and Howard V. McMurry, seem to give adequate results when searching for commercial sand or gravel deposits to be used for road-building and other purposes. The areas for best prospecting are those whose resistivity data conform to master curves having a resistivity ratio of 1:100:1. This plus high apparent resistivity readings are the two governing factors in recommending possible prospecting areas for deposits of sand or gravel.

The most consistently correctly interpreted value was depth to the top of the third layer ($h_2$). In 13 out of the 16 locations tested there was a definite correlation between the analysis of the test-hole logs and the resistivity interpretations. This has been referred to as the contact depth because it is the depth to the contact between the sand or gravel layer and the till layer. The sand or gravel may be the upper layer or the lower layer, but the fact that the contact depth was determinable is significant.

In several locations there was also a correlation between the interpreted thickness of the top layer ($h_1$) and the thickness of the second layer (d).

It is felt that where there was no apparent correlation, a detailed sampling procedure and microscopic sample study would reveal evidence supporting the interpretations by indicating lithologic breaks which would correspond to the electrical breaks shown by the interpreted resistivity data.

Test drilling bore out the prediction that Area 1 was the best area for sand or gravel deposits. It was predicted that Area 2 was a good prospecting area, and this also was borne out by test drilling in the southern part of the area. It was the deposit in Area 2 from which the Clinton County Highway Department obtained the sand and gravel for road building. Several other areas show good commercial possibilities, but leasing arrangements and other factors prevent their development at the present time.

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# CERAMIC MATERIALS FROM MAGNESIUM-TREATED CLAYS*

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Thermal expansion characteristics of the crystalline and glassy constituents of ceramic materials are important in determining their physical behavior when the ceramics are placed in service. Refractory materials sometimes fail, largely because stresses derived from differential thermal expansion of their mineral constituents cause ruptures. Cordierite is a magnesium aluminum silicate mineral which has a very low coefficient of thermal expansion. Thus a cordierite body should find wide use in ceramics.

When kaolinite is treated with various magnesium compounds, numerous high-temperature phases develop, depending upon the conditions of treatment and firing. It is believed that the formation of a high-temperature phase can be facilitated if the final crystalline structure is derived from regrouped crystalline units which in turn were derived at a lower temperature from a third crystalline material. For example, in the development of cordierite from magnesium-treated kaolinites, a uniquely crystalline metakaolin phase results following dehydration at 600°C. This combines with MgO at 1000°C. to form spinel. With further increase in temperature spinel combines with cristobalite to give cordierite.

It is not necessary to postulate that at any stage in this sequence the crystalline components were broken down into amorphous constituents which recombined to give the subsequent crystalline phase. Thus the energy requirements in going from one crystalline phase to another, with only moderate shifts in the atomic network, should be appreciably less than if the starting materials were merely mixtures of metallic oxides and hydroxides in the proper proportions to give the desired product. It seemed that cordierite bodies could be produced at lower temperatures if the starting materials were crystalline components such as clay materials.

The high-temperature phases from a variety of kaolinitic clays treated with numerous compounds of magnesium were investigated, chiefly by means of X-ray diffraction. Those formed from mixtures of $MgCO_3$ and a relatively pure kaolinite from Anna, Illinois, are representative and will be discussed here.

Test pieces, 1″ x 1″ x 3″, prepared from mixtures of kaolin and $MgCO_3$ equivalent to 6 and 12 percent MgO, were fired to 1000°, 1100°, 1150°, and 1200°C. The high-temperature phases identified are summarized in table 1. Examination of these data brings out several relationships which seem to indicate something of the effect of various factors on formation of cordierite.

* This paper was presented at the 1952 meeting. It is published with permission of the Chief, Illinois State Geological Survey.

TABLE 1.—HIGH TEMPERATURE PHASES IDENTIFIED BY X-RAY DIFFRACTION
Anna Kaolin-$MgCO_3$ (equivalent to 12 percent MgO)

| | *Cord.* | *Mullite* | *Crist.* | *Spinel* | *B-qtz.* | *Minor* |
|---|---|---|---|---|---|---|
| 1200°C..... | VS* | | W | | | |
| 1150°C..... | S | | M | ? | | |
| 1100°C..... | MS | | S | W | | |
| 1000°C..... | | | | M | S | Periclase ?<br>Forsterite ? |
| | Anna Ka | olin-$MgCO_3$ ( | equivalen | t to 6 percent | MgO) | |
| 1200°C. | M | M | S | | | |
| 1100°C. | MW | M | VS | W | | |
| 1000°C. | | | | M | | "Gamma alumina"<br>Periclase ? |

1. Maximum cordierite is produced at 1200°C. with the addition of $MgCO_3$ in amounts equivalent to 12 percent MgO, with the development of no other aluminum or magnesium phases and with minor amounts of cristobalite.

2. Comparison of samples fired to 1200°C. and containing 6 and 12 percent MgO shows that when the MgO addition is reduced, mullite forms at the expense of cordierite, and cristobalite appears in greater amounts. Raw Anna kaolin containing no MgO fires to mullite and cristobalite only. It would seem that in the magnesium-treated clay, at high temperatures, cordierite and mullite both compete for the alumina constituent, the cordierite taking all the MgO it can utilize. Any alumina left goes into the formation of mullite. If the $Al_2O_3$ to MgO ratio approximates that of theoretical cordierite, alumina and magnesia are completely used up, with none available for the formation of mullite. This appears to be what happens when the Anna kaolin-$MgCO_3$ mixture (12 percent) is fired to 1200°C., as such a mixture upon dehydration has a chemical composition approximating that of theoretical cordierite (table 2).

3. The decrease in cristobalite which accompanies the increase in cordierite as more magnesium is added to the system suggests that cristobalite is used up in the development of cordierite.

4. Comparison of phases developed at various firing temperatures shows an increase in cordierite with increasing temperature, accompanied by a decrease in cristobalite. The MgO is tied up in phases other than cordierite at the lower temperatures. At 1000° and 1100°C. the phase is spinel.

* VS = Very strong.
S = Strong.
MS = Moderately strong.
M = Moderate.
MW = Moderately weak.
W = Weak.

TABLE 2.—CHEMICAL COMPOSITIONS

| | *Anna Kaolin 12% MgO (Percent)* | *Theoretical Cordierite (Percent)* |
|---|---|---|
| $SiO_2$ | 49.8 | 51.4 |
| $Al_2O_3$ | 36.4 | 34.9 |
| MgO | 13.8 | 13.7 |

Thus the following sequence of events leading to the development of cordierite is suggested. When kaolin is treated with the equivalent of 12-percent MgO (sufficient to give a total chemical composition approximating theoretical cordierite), magnesium and aluminum are tied up in a spinel phase at 1000°C. As the temperature is elevated, cristobalite develops and the spinel becomes unstable, its aluminum-magnesium components combining with cristobalite to form ever-increasing amounts of cordierite. As the temperature increases cordierite continues to increase at the expense of spinel and cristobalite until ultimately at 1200°C. only cordierite and minor amounts of cristobalite are present.

When lesser amounts of MgO are added to the clay, this sequence is modified. At 1000°C. the magnesium is tied up in a poor spinel phase and the alumina in another poorly crystalline phase, probably gamma alumina. As the temperature is raised, the spinel becomes unstable, cristobalite forms, and the two start combining to give cordierite. The gamma alumina is used up in the formation of mullite. As the temperature is raised still higher, more cordierite is formed until at 1200°C. cordierite, mullite, and cristobalite remain.

Thus by varying the treatment of kaolinitic clays with magnesium, a variety of products can be obtained which contain various relative proportions of cordierite, mullite, and cristobalite. Likewise, clays of differing composition show differences in the amounts of high-temperature phases formed. Bodies high in cordierite can be made from common fireclays, which are dominantly kaolinitic but contain appreciable amounts of micaceous clay minerals and quartz. A wide variety of ceramic materials can therefore be developed which exhibit a diversity of properties. Samples containing cordierite as the major constituent are denser and exhibit considerably greater resistance to thermal shock than their non-magnesium-treated equivalents. Their refractoriness is diminished somewhat as MgO is added so that consideration must be given to choosing that property which is most important for each application.

This preliminary laboratory study of such materials can serve as a point of departure for large-scale studies in evaluation of cordierite bodies for commercial use.

Acknowledgments

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# PHYSICS

## APPLICATIONS OF NUCLEAR MAGNETIC RESONANCE*

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The nuclear magnetic resonance effect was predicted during the 1930's, but it escaped experimental detection until 1946 when the technique for observation was worked out simultaneously by Block at Stanford and Purcell at Harvard. We shall follow the Purcell method here.

Suppose that we place a sample of material in a strong, homogeneous magnetic field which we shall denote by $H_z$. If the nuclei in the sample have magnetic moments and spin I, then they will have $2I + 1$ stable energy states, the lower energy states occurring when the nuclei are more nearly aligned with the field. The nuclei precess about the magnetic field at the Larmor frequency, given by $\omega = \gamma H_z$, where $\omega$ = the angular frequency of precession and $\gamma$ = the gyromagnetic ratio. At room temperature the interaction energy $\mu H$ (where $\mu$ = the magnetic moment of the nuclei) is much smaller than the thermal energy, kT. Thus, there will be only a small excess population in the lower energy states. Let us consider, as an example, protons which have ½ integer spins. In a field of 10,000 gauss, there will be about 1,000,040 protons in the lower energy state as compared to 1,000,000 in the higher energy state. It is this excess of 40 nuclei in the lower energy state which we can observe.

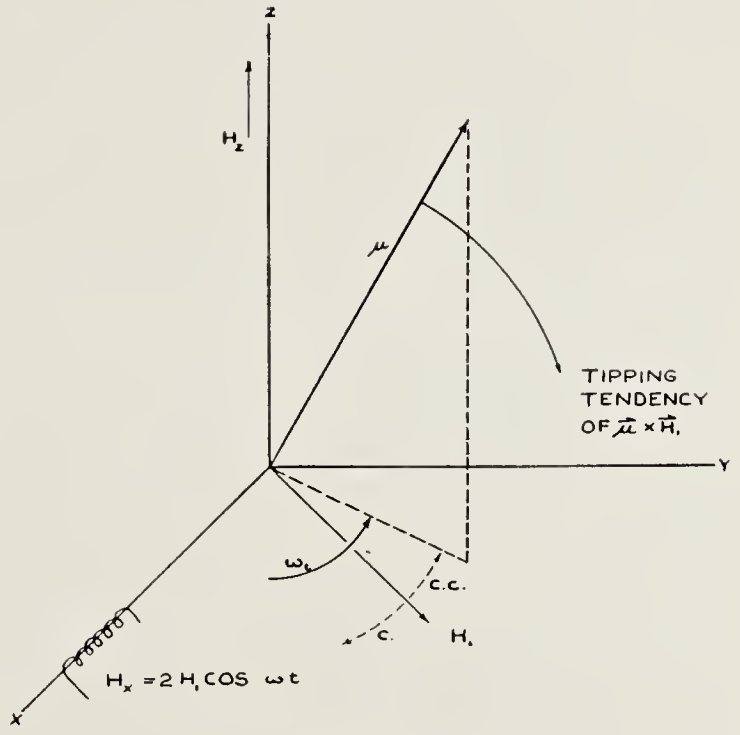


FIG. 1.

If the sample is placed inside a coil which is perpendicular to the applied magnetic field $H_z$, and a radio frequency voltage applied to the coil, there will be a small magnetic field of radio frequency, which we shall denote by $H_1$, inside the sample and perpendicular to the static field $H_z$. The r.f. field may be considered to consist of two circularly polarized components rotating in opposite directions about $H_z$ (fig. 1).

If the r.f. field is applied at the Larmor frequency, then one of the rotating components will produce a torque $\vec{\mu} \times \vec{H}_1$ on the precessing magnetic moments, tending to tip them over. The component of $H_1$ rotating in the same direction as $\mu$ produces a tipping torque; the component rotat-

* This research is supported by a grant from the Research Corporation.

ing in the opposite direction cancels out since there will be a torque tending to flip spins up for as much time as there is a torque tending to tip them down.

During the time the spins are being flipped over, power is absorbed in the sample coil. Phenomenologically, this is equivalent to a change in the magnetic susceptibility of the sample. Thus, the effective inductance and resistance of the sample coil change during the flipping of the spins. The spins would all be flipped in a very short time if there were no coupling of the spins to the external environment, and thus, the signal would be very short. However, since there are thermal motions of nuclei in the sample (these will be the lattice vibrations in the case of a solid, and random molecular motions in the case of a liquid) the spin system can interact with these degrees of freedom, and lose its excess energy to it. The spin system, after having absorbed r.f. power, may be thought of as analagous to a piece of hot metal in contact with a thermal bath. The spin system, just as the piece of metal in the analogy, will cool down exponentially. The time required for all but 1/e of the equilibrium excess of spins to reach their lower energy state is denoted by $T_1$, and is referred to as the spin-lattice relaxation time. Obviously, $T_1$ depends upon the structure of the material.

In addition to the spin-lattice relaxation, each nuclear spin interacts with neighboring spins through their magnetic fields. Thus the magnetic field at the nucleus consists of the applied field $H_z$ and the local field caused by neighboring nuclei. The local field is different at different nuclei, owing to the different possible orientations of the neighbor spins. This effect thus leads to a broadening of the line. The magnitude of this local field is of the order of a gauss in solids. One can also assign a time perameter to this broadening effect, since $\omega' = \gamma\ \delta\ H$, where $\delta H$ is the local field variation over the nuclei and $\omega'$ is the corresponding frequency spread. Then we define $T_2 = \frac{2}{\gamma\ \delta\ H}$. This type of interaction is called the "spin-spin" relaxation time.

There are, of course, other sources of line broadening. For example, $T_1$ itself contributes to the line width, as do any inhomogeneities in the applied field $H_z$. Still other sources of broadening are due to the uncertainty principle, saturation broadening and quadrupole broadening, if any nuclei are present which possess an electric quadrupole moment. Thus the line width and shape depend upon the structure of the sample. $T_2$ varies from $10^{-5}$ sec to about 2 sec.

The apparatus used for the detection of the resonance signal is shown in figure 2. (All apparatuses used were based on the same principles but varied somewhat in their details.) The magnetic field $H_z$ is swept back and forth approximately 1 gauss about its normal value. The r.f. signal generator is set on a frequency such that the resonance occurs when $H_z$ is at about the middle of its sweep. A bridge is used simply to prevent saturation of the receiver by the oscillator. The bridge is then balanced, and since the cathode-ray tube sweep may be thought of as

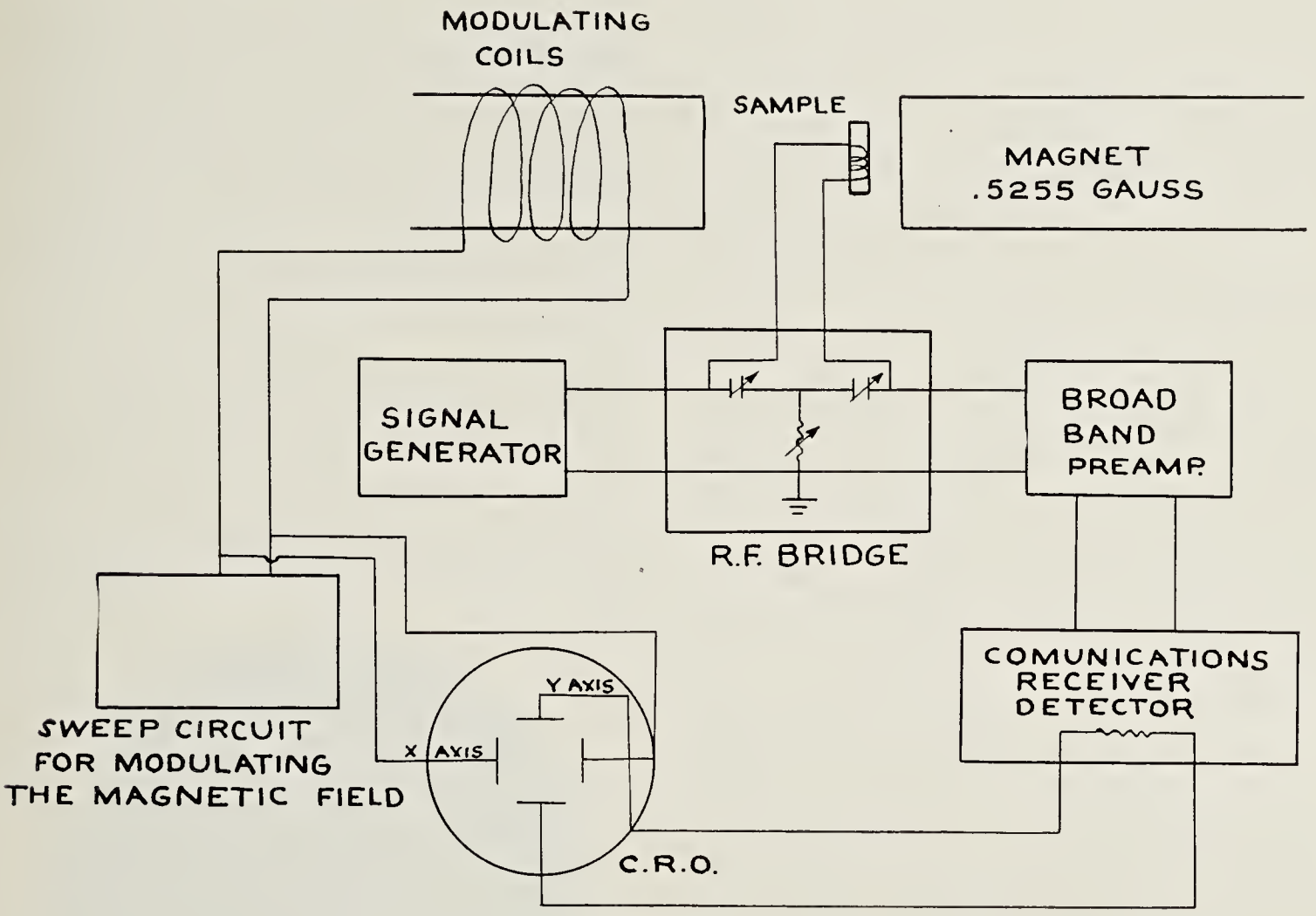


FIG. 2.

plotting gauss on the x axis, a signal appears on the screen as a plot of signal vs magnetic field.

Figure 3 (left) shows such a plot for glycerine. The sweep length is about .4 gauss, and the sweep time about 3 seconds. The line width of about 30 milligauss is here due to the inhomogeneity in $H_z$. Figure 3 (right) shows the dispersion curve, which is obtained by a somewhat different type of bridge unbalance.

There are many applications of the method, such as the study of chemical structure, structure in solids, measurement of diffusion constants, etc.

It was discovered quite early that when paramagnetic ions are added to water, the proton spin-lattice relaxation time decreases from about 2.3 sec to $10^{-3}$ sec, the relaxation time being proportional to the concentration of paramagnetic ions. Selwood and his group utilized this effect to study the rate constant of the reaction $Eu^{++} \rightarrow Eu^{+++} + e^-$ catalyzed by zinc. By simply measuring $T_1$ as a function of time after introducing zinc into the $H_2O + Eu^{++}$, the reaction rate could be determined.

Pake and Gutowski found the line shape for compounds in solid form containing groups with two protons to be similar to that shown in figure 4. (In this case the phase-unbalance,

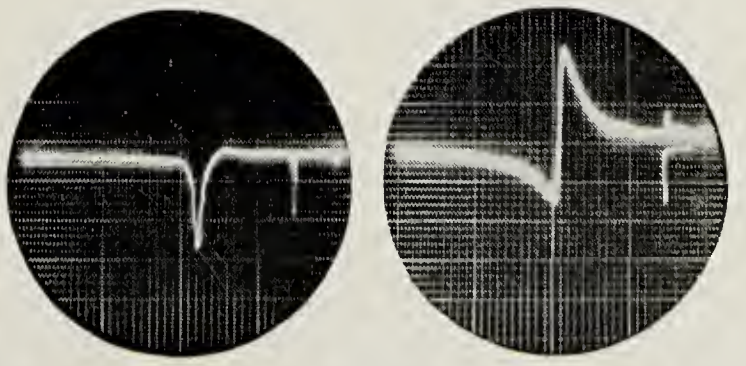

FIG. 3.

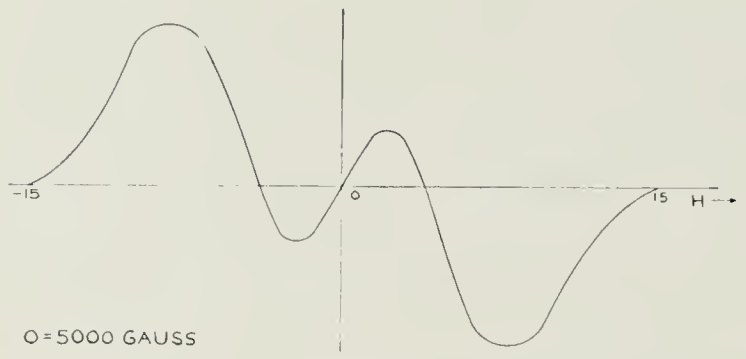


Fig. 4.

or inductive change in the sample, is shown.) An analysis of this system by Van Vleck led to values of the proton-proton bonds distances in 1, 2 dichloroethane. Similar investigations have been carried out with other compounds.

The line shape for a 3-proton system is shown in figure 5. A group at the University of Tokyo utilized this difference in line shape between the two kinds of groups to prove that in hydrogen perchlorate monohydrate (H Cl O4 · $H_2O$), the water of crystallization is bound as the oxonium ion ($OH_3^+$).

In 1949, Knight found that the position of the resonance depends to some extent on the chemical bonding of the nucleus. This effect is due to the small local field produced at the nucleus by the orbital electrons. This "chemical shift" has been studied extensively by Arnold and Packard at Stanford and Gutowski at the University of Illinois. They have utilized this small shift, which ranges from a few milligauss up to a half gauss, to study the electron distributions in

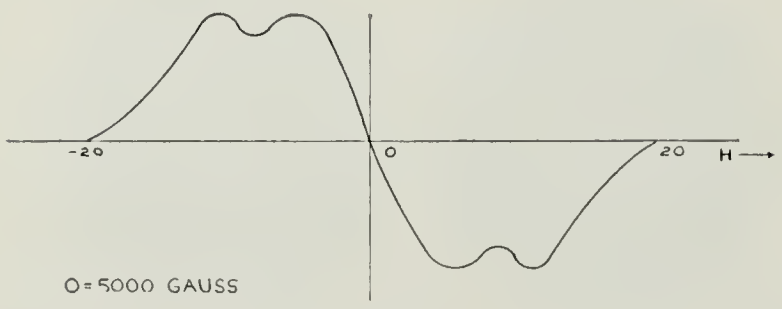


Fig. 5.

a number of organic and inorganic phosphorous and flourine compounds. More recently, it has been found that a number of these compounds do not have single lines, but have a number of lines. From this Gutowski and Slichter have shown the existence of a coupling between nuclei in a molecule through the orbital electrons. Experiments of this type require an extremely homogeneous magnetic field.

Our research program consists of applying these effects to suitable

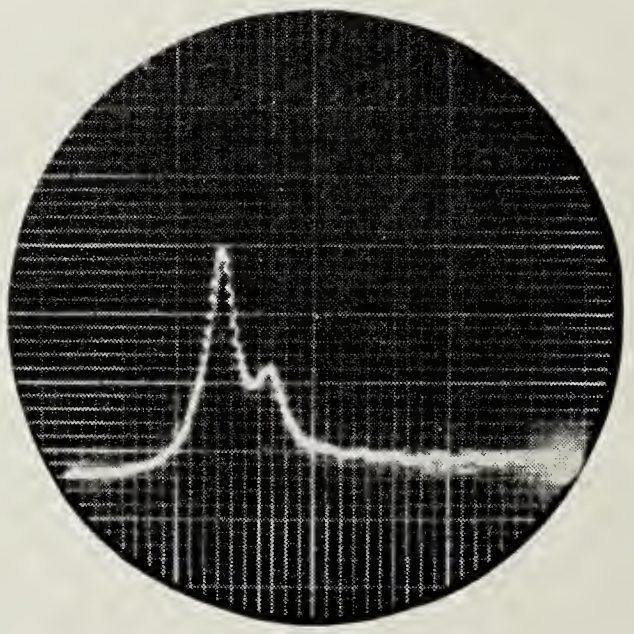

Fig. 6.—Protons in acetic acid showing —COOH peak separated from —$CH_3$ peak.

problems in biochemistry and pharmacology. The problem to which we are devoting most of our efforts involves the inactivation of the enzyme cholinesterase by diisopropyl fluorophosphate (DFP). The question is, Is the fluorine transferred to the cholinestarase molecule? Also, we are attempting to measure the rate constant of the reaction. The fluorine resonance in DFP consists of two lines. If the fluorine is transferred to the cholinesterase molecule so that it is bound to a different atom phosphorous, the splitting should disappear, and the resonance position shift

slightly. The rate of disappearance should be proportional to the rate of change of the relative amplitudes of the signals from the unreacted DFP and the reacted DFP. If the fluorine is merely transferred to the solution as free $F^-$, the shift will be different than if it is transferred to the cholinesterase.

There are a large number of such problems in biology which should lend themselves to solution by this technique.

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# NEGATIVE PHOTO-EFFECT IN HELIUM

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## Excitation States of Helium

The states of helium excited by electron impacts are shown in figure 1. In the left column appear the singlet states of the normal atom in which the spins of the two electrons are anti-symmetric. The term *parhelium* was originally applied to this form of excited helium emitting singlet lines. If, in the process of excitation, the spin of the emission electron is reversed, a series of triplet states results. The name given to atoms having these configurations is *orthohelium.*

The parhelium state 1s 2s $^1S_o$ is metastable. The corresponding state of the orthohelium configuration, 1s 2s $^3S_1$, is also metastable. The latter forms the "ground" state of the triplet system. Atoms in either of these states cannot return to the normal ground level by simple emission of radiation. Although both can lose their energies by collision processes, there is one respect in which they differ. An atom in the parhelium metastable state can be transformed to a normal helium atom by absorption of radiation which lifts it to a higher excitation level, from which it can return to the ground state by the emission of spectral lines. Orthohelium atoms can return to normalcy only by some collision process.

The line most strongly emitted by parhelium is the line at 2.0582 microns. The corresponding emission by orthohelium consists of three lines at 1.08304, 1,083025, and 1.082908 microns, the last three lines being unresolved by most spectrographs. Conversely, all of these lines are strongly absorbed by atoms in the corresponding metastable states. One method used in this laboratory to determine the relative abundance of atoms in the two states in a discharge is to measure the absorption of these lines emitted by a bright helium gas source and sent through the excited gas.

## Infrared Line Radiations

Many measurements of the relative intensities of the two "resonance" type of lines arising from transitions from the next higher level to the metastable levels in helium have been carried out in this laboratory. In Geissler glow discharges the ratio of the emitted intensities at 1.0830$\mu$ and at 2.0582$\mu$ varies strongly with pressure. It is a nearly linear relationship, varying from a value of 4:1 at .5 mm Hg pressure to about 50:1 at 10 mm Hg pressure. The ratios are slightly higher at higher currents in the range from 10 to 80 milliamperes. In the case of arc discharges, the ratios vary from about 12:1 at 8 mm Hg pressure to more than 100:1 at higher gas pressures.

These results indicate that parhelium metastables are rapidly destroyed through absorption of radiation as well as by collisions, these effects becoming more efficient as the gas pressure and current densities are increased. Orthohelium metas-

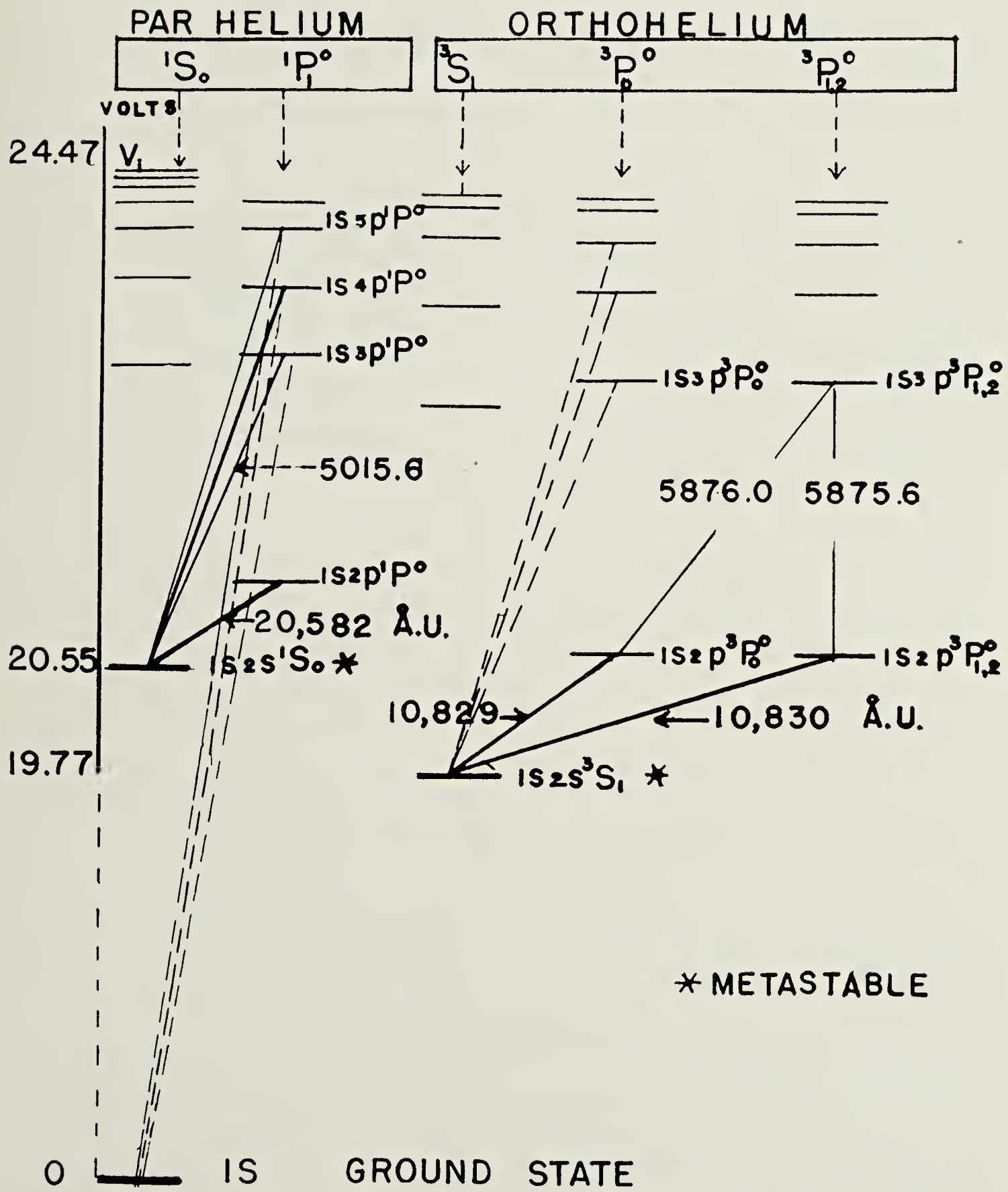


Fig. 1.—Energy level diagram of He atom.

tables are destroyed by collision processes only and by diffusion to the walls or electrodes of the discharge chamber.

### Change of Current Produced by Light in Glow Discharges

When light emitted by a strong glow discharge in helium is allowed to shine upon a second discharge, the current in the second tube decreases and the potential increases. However, these changes are small, particularly for discharges in narrow capillary tubes. Results obtained for radiation from one Geissler discharge allowed to fall on a second tube placed parallel to it about 3

inches away is shown in fig. 2. If the light is focussed on various parts of the second tube it is found that 90% of the effect occurs when the negative glow region near the cathode is irradiated. No effect is found in the positive column of the glow where metastable atoms make a neg-

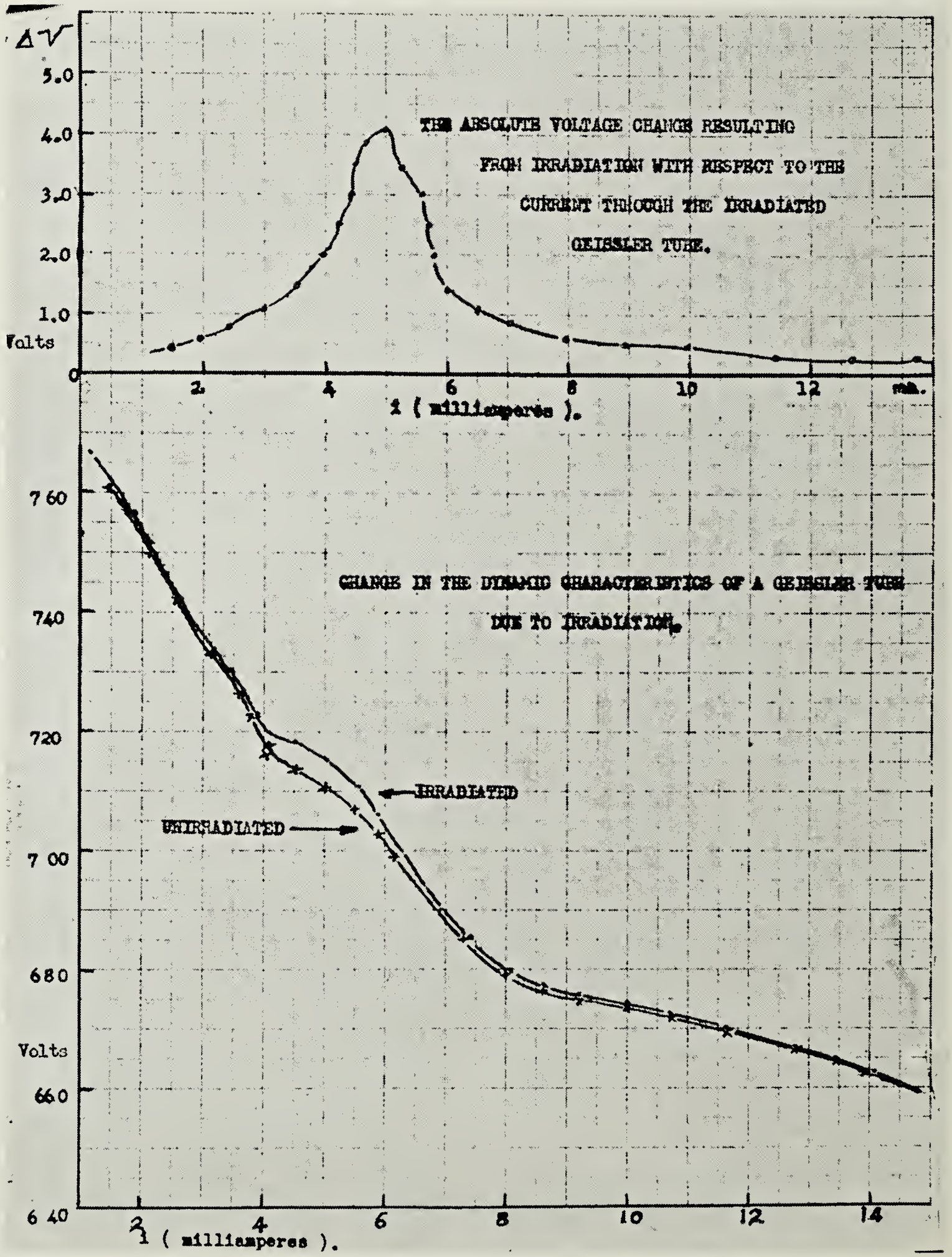


FIG. 2.—Change in characteristic of Geissler discharge due to 2.0582 $\mu$ radiation.

ligible contribution to the maintenance of the discharge.

Careful studies were made on the effect produced by both the 1.0830$\mu$ line and the 2.0582$\mu$ line on the discharge. Using both a spectrometer and filters it was found that no measurable change is caused by the 1.0830$\mu$ line. The conclusion has since been confirmed that only the 2.0582$\mu$ line affects the discharge. This result is understandable as only parhelium metastable atoms can be destroyed by light. Even though both types of metastable atoms may promote ionization processes in the gas, only the parhelium metastable state can be permanently affected by the absorption of line radiation.

## Role of Metastable Atoms in the Discharge

Several years ago it was established in this laboratory that metastable atoms play a significant role in Townsend currents in an argon-filled cesium phototube. The current between parallel plates of a phototube in which a current of emitted electrons, $i_o$, is caused by light falling on the cathode is given by

$$(1) \quad i = \frac{\propto |x - \delta|}{i_o \, \epsilon \left( 1 - \gamma \left( \frac{\propto |x - \delta|}{\epsilon} - 1 \right) \right)}$$

In this equation $i_o$ is the electron current which would flow due to light if there were no gas in the tube; x is the separation of the parallel plates in cms; $\propto$ is the number of ion-electron pairs produced by collision of electrons with gas atoms; $\delta = V_i / E$, where $V_i$ is the ionization potential of the gas and $E = V / x$ is the field intensity, and $\gamma$ = the average number of secondary electrons emitted from the cathode per positive ion reaching it. The coefficients $\propto$ and $\gamma$ determine the amplification constant $K = i / i_o$ for a gas-filled phototube.

It was found that the secondary Townsend coefficient $\gamma$ appearing in this expression must include the effect of metastable atoms which diffuse to the cathode and release electrons, as well as the effect of ions. In other words

$$(2) \qquad \gamma = \gamma_m + \gamma_p$$

Here $\gamma_p$ represents the release of electrons due solely to the ion, while $\gamma_m$ is the effect of metastable atoms in releasing electrons. It turns out that $\gamma_m$ and $\gamma_p$ are of the same order of magnitude at p = 1 mm Hg pressure. For Cs-Ag-O cathodes $\gamma_m \cong \gamma_p \cong .2$. Although metastable atoms and ions are formed in about equal numbers, only a part of the metastable argon atoms diffuse to the cathode. All of the ions formed in the discharge are drawn to the cathode by the field.

In these experiments at pressures $p \leqq .8$ mm Hg, the main effect of metastable atoms is at the cathode in releasing electrons to the discharge. Current densities were of the order of $10^{-8}$ or $10^{-7}$ amp/cm$^2$.

At higher pressures and at larger current densities metastable atoms contribute to the discharge in other ways. They may effectively ionize impurity vapors or foreign gas atoms, or they may, by collision with each other, produce electron-ion pairs. Thus, if He* represents a metastable He atom,

$$(3) \qquad He^* + He^* \rightarrow [He_2^+ + e^-] \rightarrow He^+ + He + e^- \quad .$$

This stepwise ionization process can be significant in a pure gas at elevated pressures and high excitation densities. The frequency of collision of metastable atoms with each other varies as $n^2$, where n is the number of metastable atoms per $cm^3$ in the discharge space.

One of the objectives of the present research is to attempt to determine in a particular discharge how much metastable atoms contribute to the discharge by release of secondaries ($\gamma$—mechanism), and how much they contribute by other processes which occur in the gas phase (volume effect). Because from the results obtained with a glow tube it was found that destruction of parhelium metastable atoms produces a measurable effect only in the near-cathode region of the discharge, it was decided to build tubes in which only the negative glow occurs. Such tubes are referred to generally as negative glow lamps, and include such forms as the hollow cathode glow and gas-filled phototubes. The negative photo effect is found to be largest at rather low pressures, since presumably collisions and radiations within the discharge itself greatly reduce the population of parhelium metastable atoms.

## Effect of 2.0582 Micron Line on Photo Currents

A number of helium-filled phototubes were prepared having regular activated cathodes and high purity gas. Cathodes of both cesium-silver-oxide and cesium-antimony types were used. Gas pressures for the former ranged from .5 to 3.0 mm Hg, and for the latter from 1 to 3 mm Hg. These tubes were made for this work by R. W. Engstrom of the RCA Tube Laboratory, Lancaster, Pa.

These tubes are not operated in the normal manner as photo-detectors. Instead, a series resistance of from 4 to 100 megohms is connected in series with the tube and a d-c voltage source higher than the breakdown potential of the gas. At the higher pressures this potential is about 120 volts at 3 mm Hg pressure, but it is of the order of 400 volts at the lowest pressures used. The tube requires no external light for its operation. Upon breakdown the IR drop in the resistor limits the current to values in the range of from $10^{-10}$ amperes to 10 or 20 microamperes as may be desired by change of the input voltage. The activated electrodes are not damaged by prolonged operation at the higher currents.

This type of "dark" discharge is referred to as a "self-maintained" Townsend discharge. The reason for this name is that no space charge and hence no cathode fall space is created. The electrodes may be parallel plates or a wire and semi-cylinder arrangement. The present tubes are of the latter type, and either electrode may be made the cathode. When the activated surface is the cathode, the potential across the discharge is lower than for the reverse polarity. This potential is constant over a range of current values from $10^{-9}$ to $10^{-6}$ amperes. Beyond about 1 microampere the potential drops linearly with increase in current through the tube.

The circuit used for operating the helium phototubes is shown in figure

3. Both a 350-volt rectifier supply and a bank of 45-volt dry batteries have been used as a source of potential. An electrostatic voltmeter reading up to 300 volts is used to determine the voltage across the discharge tube. Currents are read by a galvanometer or microammeter.

When line radiation at 2.0582 microns from a high-intensity 60-watt helium arc operating at about 18 mm Hg is allowed to fall on the excited gas in the phototube, the current decreases and the tube potential increases. A Bausch and Lomb glass filter, which passes only wave lengths beyond 1.3 $\mu$, was used between the light source and the tube. Changes in the volt-ampere characteristic due to radiation of a tube containing helium at a pressure of .55 mm Hg are shown in figure 4. The dotted lines show the shift of the characteristic with a constant light flux shining on the tale.

The current change produced by the light with the source about 3 inches from the phototube is remarkably constant over the range from 1 to 12 microamperes. It is about .5 $\mu$ amp. and is progressively smaller for tube currents below one microampere. Apparently there are only so many quanta available for absorption in the 2.0582 $\mu$ line radiation from the source, and the constant current change represents a saturation effect. This phenomenon occurred in all of the measurements. The corresponding voltage change is about .6 volt for the data shown in figure 4.

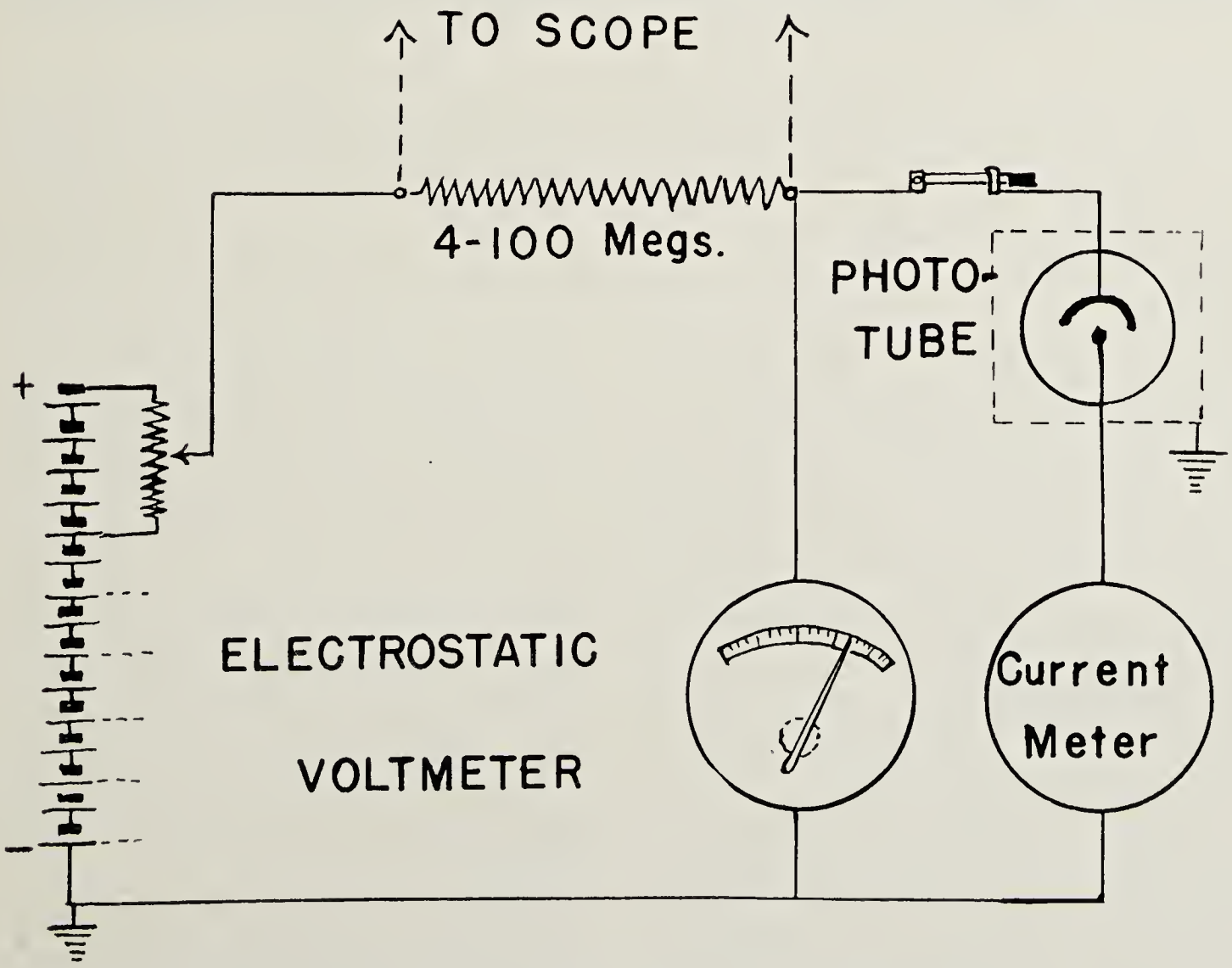


Fig. 3.—Circuit for detecting negative photo-effect.

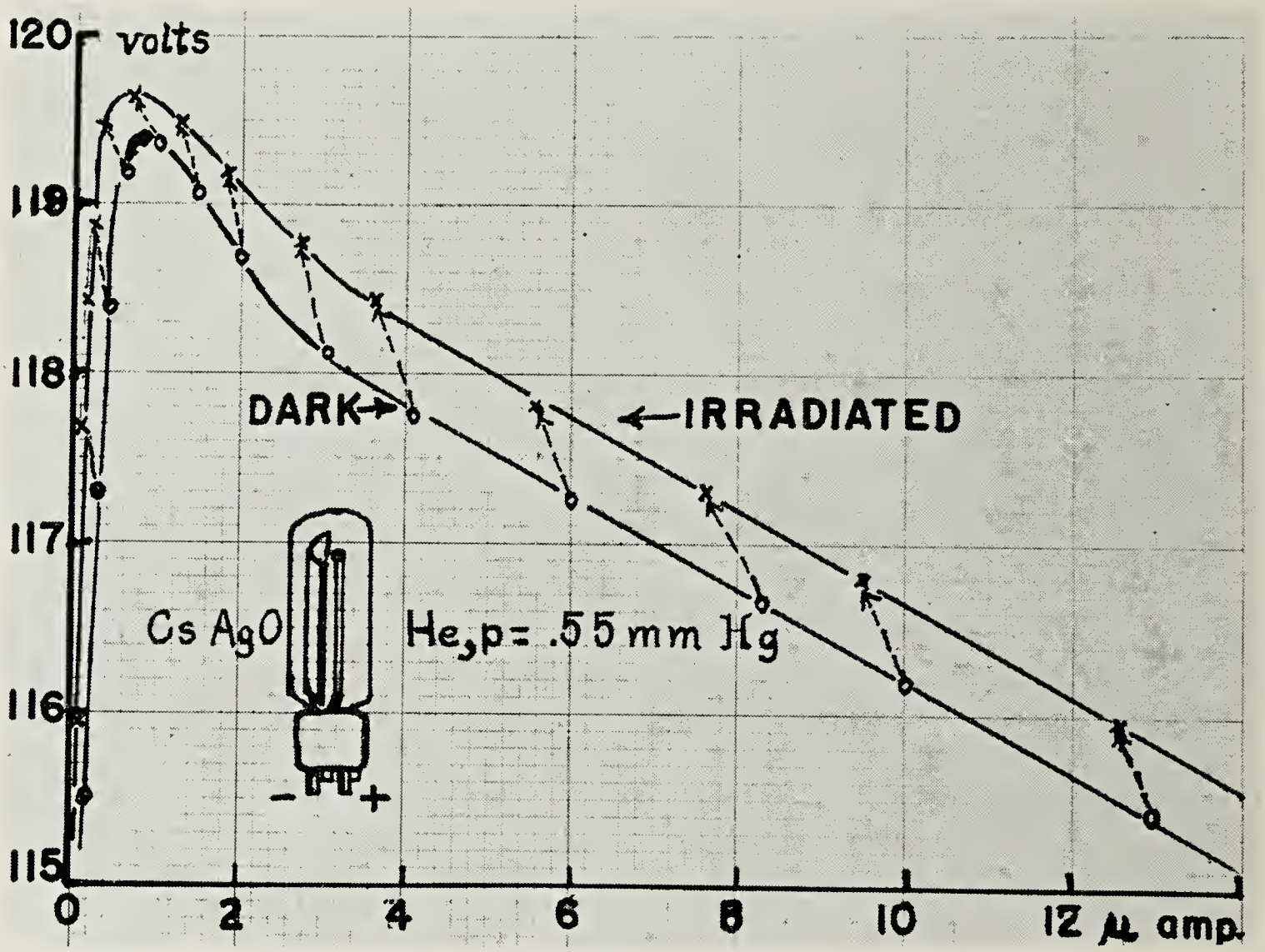


*Fig.* 4.—Negative photo-effect in He phototubes.

The current changes caused by a given light flux are larger when the tube is connected with the activated cathode positive. Since the $\gamma$—mechanism for metastable atoms causing release of electrons must be very small in this case, since the wire electrode used as cathode is not activated, and since also it has a very small area for intercepting the diffusing metastable atoms, their role in the discharge must be a volume effect. Measurements are being carried out to determine the lifetime of metastable atoms in these discharges. To date the mean lifetimes appear to be a few milliseconds.

Another method of investigation being used is to employ modulated or pulsing radiation. The time response of the phototube current to this light is determined by applying the potential across the series resistor of figure 3 to an oscilloscope. The signal detected may then be analyzed to determine the presence of more than one kind of current change as a function of time.

Figure 5 shows four oscilloscope photographs made using the helium arc operated from the output of a 60-cycle 650-volt transformer. There are 120 half sine wave loops per second. The effect of these light pulses is shown in figure 5a where unfiltered light of the arc falls on the helium phototube with cesium surface used as cathode. In this the tube responds as a normal phototube, with positive current loops turned upward.

Figure 5b shows the results obtained when the phototube is connected with the wire used as cathode.

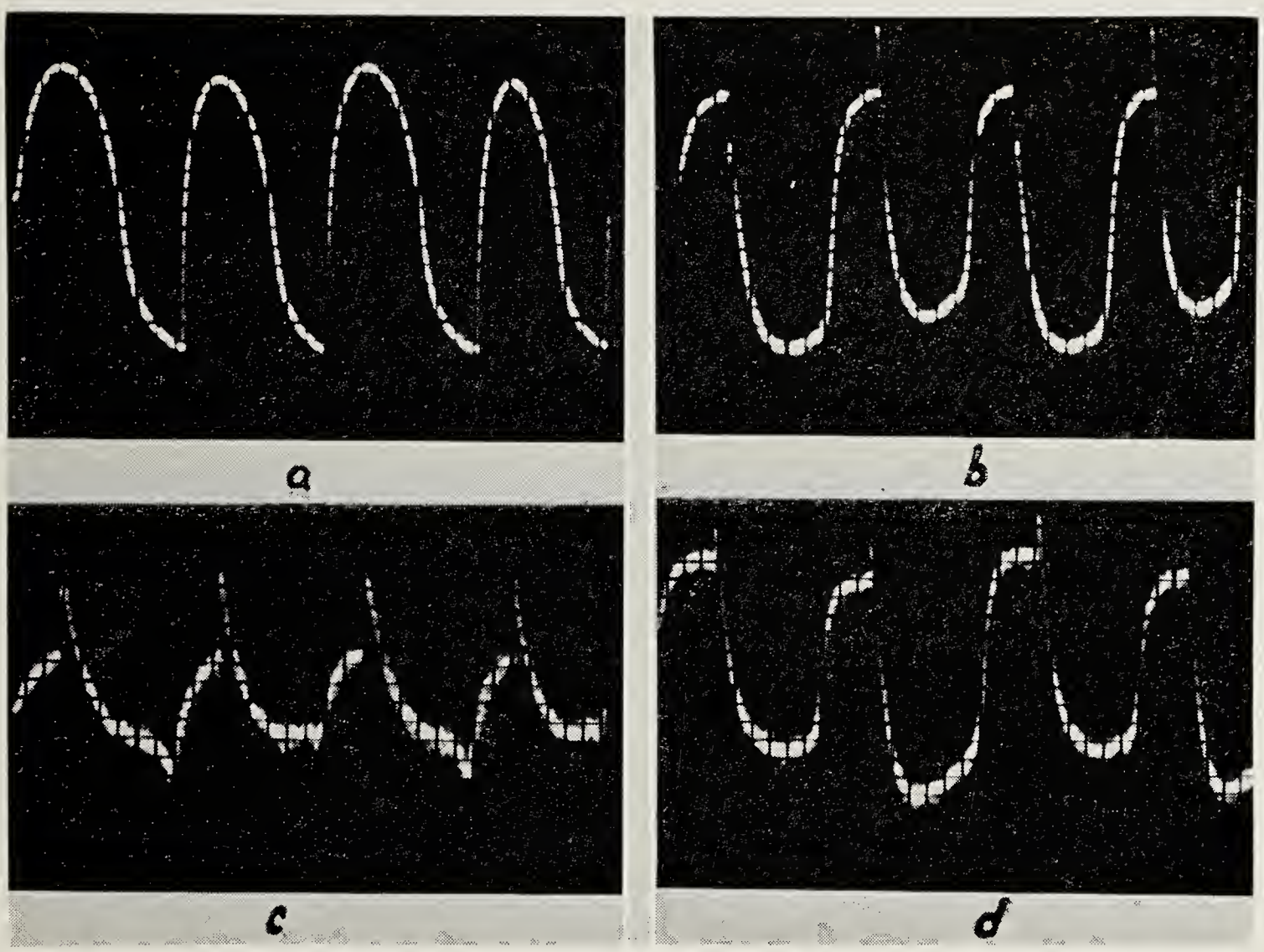


FIG. 5.—Negative photo-effect using pulsed radiation. (a) Positive wave pulses from A-C helium arc; p = 3 mm Hg. (b) Negative current pulses, Cs-Ag-O surface positive. (c) Negative current pulses, Cs-Ag-O surface negative. (d) Negative pulses, Cs-Ag-O negative; p = 55 mm Hg.

The shape of the current pulses are similar to those shown in figure 5a. In this case, however, the loops appear reversed and represent the effect of absorption of 2.0582 $\mu$ line radiation. The pulses represent *decreasc* of current in the tube with increasing light intensity.

Figure 5c shows the negative current pulses produced when the cesium activated electrode is the cathode, the image of the arc light being carefully focussed on the gas in the region of the collecting wire electrode. In this region metastable atoms are most dense. Absorption of light and decrease of current sets in as the light intensity increases. However, there is a pronounced lag in response of the cell, and at about three-fourths of a half period later, an additional negative tip in the current loop is observed. This is believed to be a rather sudden change, occurring when there is a "hole" in the supply of metastable atoms which normally reach the cathode, causing a further sudden decrease in current. The relative change is small and presumably the volume effect of metastable atoms is greater than the $\gamma$-action, causing release of secondary electrons from the cathode surface.

The tube used in the above experiments had a pressure of 3 mm Hg of helium gas. Figure 5d shows the results with light focused near the

positive wire electrode in a tube in which the pressure is .55 mm Hg. No distinct pip appears in the pulse, but initial decrease of current is much more rapid. In alternate pulses a distortion is present, indicating release of secondary cathode electrons but contributing to the current decrease much earlier in the period than in the first. This interpretation is reasonable since the rate of diffusion of metastable atoms is much more rapid at .55 mm Hg than at 3 mm Hg.

## Conclusions

The existence of a negative photoeffect in pure helium has been confirmed. In phototubes containing helium in the pressure range from .25 mm to 3.0 mm Hg a readily measured decrease in current is obtained when the gas is irradiated with the arc line of helium in the infrared at 2.0582 $\mu$. It is shown that a similar effect is not produced by the 1.0830 $\mu$ line of helium, although the latter is much more intense in the arc source. The results show that in phototubes having a wire cathode and at currents greater than 2 microamperes per $cm^2$ the action of the metastable atoms is predominantly that of volume ionization. It is also believed that secondary emission of electrons, induced by metastable atoms arriving at an activated Cs cathode, contributes less to the discharge mechanism than ionization produced by metastable atoms in the gas itself.

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# PSYCHOLOGY, EDUCATION AND SOCIAL SCIENCE

## TRANSLUCENT SCREEN FOR TEACHING AND TESTING

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In recent years the use of projection material has become an accepted and approved classroom technique. Projected materials are adaptable to any field and their use is to a large extent limited only by the ingenuity of the teacher. The popular use of the thirty-five millimeter camera has given the teacher the opportunity to present material that is not commercially available in 2″ x 2″ slides.

The projection equipment offered today is extremely versatile, but has some disadvantages which are not conducive to good teaching practices. Funds are not always available to provide more than the barest essentials for slide projection—usually no more than the combination 3¼″ x 4¼″ slide projector and opaque projector so popular some years ago. A method is here suggested that would eliminate some of the disadvantages of usual projection methods. Particular emphasis is placed upon the use of projected slides in biology-laboratory testing.

The most common objections to the usual methods of slide projection are the necessity of darkening the room, which precludes note-taking by the students; and the necessity of operating the projector from the back of the room, which places the teacher-operator at a distinct speaking and pointing disadvantage. Any means by which these can be eliminated is highly desirable.

Several methods for improving such adverse situations have been devised, many of which, however, require costly equipment or special installation. The following are some of the methods:

1. The overhead projector
2. Individual desk lights
3. Special projection rooms with ceiling spotlights
4. Special screens for use in lighted rooms
5. Partial darkening of the room
6. Use of a commercial translucent screen

Although the translucent screen has been used successfully in industry and advertising, Kinder (1950) feels that it has little value for school use because it is limited to situations in which the group members are both near and directly in front of the screen. However, the screen suggested in this paper has actually been viewed by classes of 35 to 40 students. The viewing angle for some students was as little as 28 degrees. The maximum viewing arc is about 122 degrees. The students had no viewing difficulties whatsoever and reported that they could see details clearly from 25 feet. The classrooms in which the apparatus has been used were 26 feet wide and varied in length from 25 to 35 feet. There is

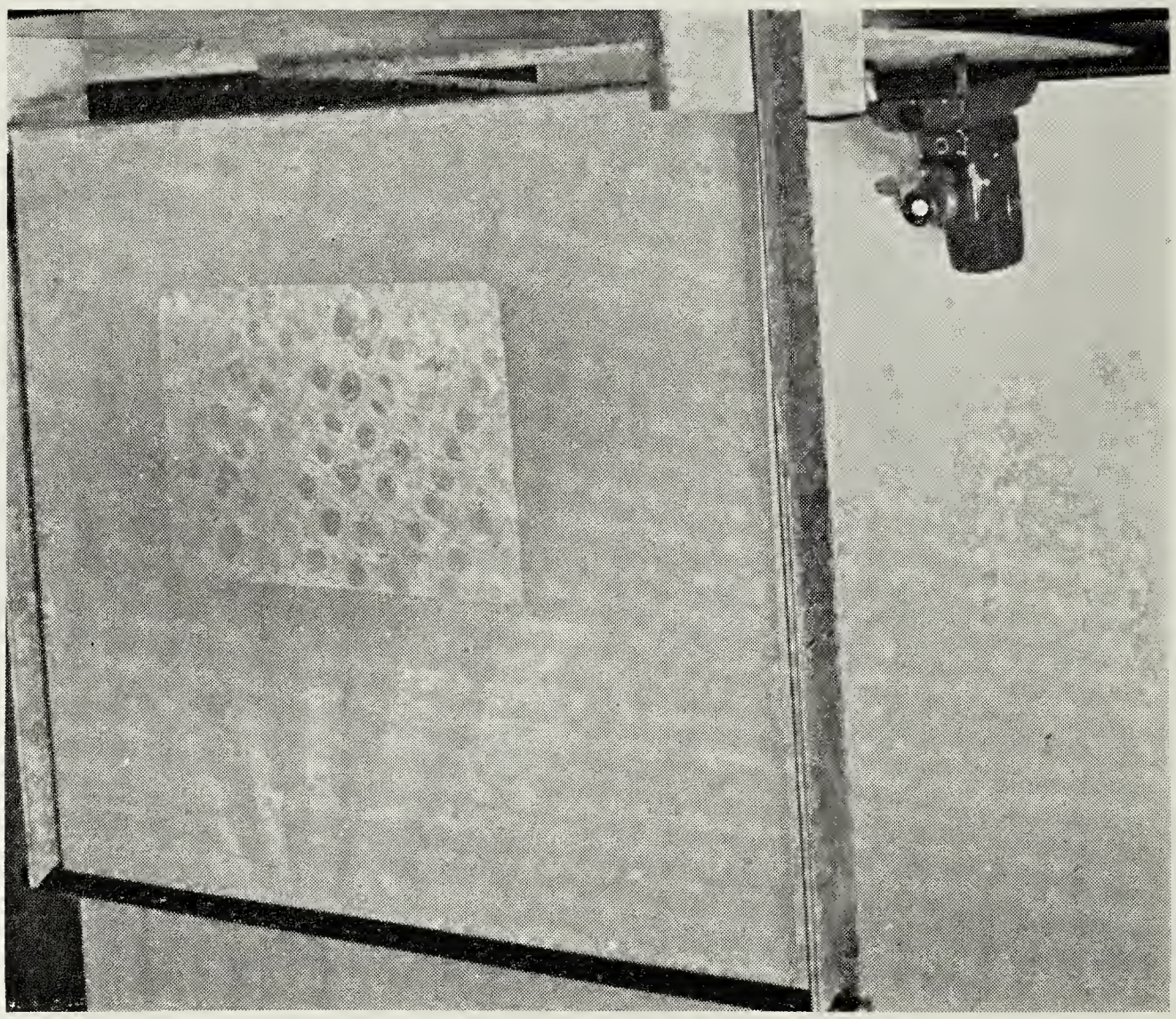

FIG. 1.—The translucent screen in operation.

little distortion at a close viewing distance and the transmitted light is soft enough to cause no discomfort to the eyes.

An inexpensive and very satisfactory screen can be made from drafting linen. This can be obtained in various sizes from civil or architectural engineers. The surface of the cloth may be coated lightly with any inert oil, such as paraffin oil, to improve the light-transmitting qualities. A mineral oil should be used because other oils are susceptible to decay. The treated cloth can then be laced tightly to a frame made of one-by-two inch wood.

Since most projectors come equipped with a five-inch focal-length lens, it is desirable to substitute one of shorter focal length. The writers have found that a three-inch lens in a projector placed four or five feet behind the screen will give a sufficiently large projection. Since projected images are normally reversed by the lens, it is necessary to reverse the slides when placing them in the projector. This will give a laterally correct image.

The lens represents an investment of twenty to twenty-five dollars, but it is not restricted to this use only. It may be used in all normal projection situations. The cloth will cost about one dollar, and the wood for the frame not more than three dollars. Thus, the total cost of the equipment is less than thirty dollars.

In the classroom, all material ordinarily projected can be used. Since the teacher is operating the pro-

jector, there is no waiting for a slide change, or distracting click in his requesting a slide change. This places the teacher-operator in a good speaking position, and near the screen to indicate specific points on the slide. The room can be illuminated normally.

## Testing

The physical set-up for practical examinations commonly used in the biology laboratory is not generally conducive to the best student performance. Since each student must move about the room answering questions at each of a number of different microscopes, serious difficulties are experienced:

1. Microscope pointers may be moved accidentally.
2. Microscopes may be out of focus.
3. Slides may be bumped.
4. Student's time at each microscope is limited.
5. Students must carry paper and pencil about the room.
6. The best light is available for only a few microscopes.
7. It is difficult for the student to understand written questions.

By using the translucent screen and a microprojector or by projecting photomicrographs, the instructor has full control over the focus of the slide and the pointer used. The students have more time for each question and do not have to leave their seats. There is always adequate illumination for writing answers, and the instructor can make his questions clear when explanations are necessary. All the advantages cited for use in the classroom also apply to the testing procedure. In addition to this, the instructor spends considerably less time in setting up the examination. Photomicrographs in color or black and white are available commercially at a reasonable price, or more suitable transparencies can be made by the instructor.

The translucent screen can be used successfully in the classroom. It is an inexpensive and convenient method of overcoming the cited objections to the ordinary slide projection situation, the high cost of special equipment, and the undesirable physical aspects of laboratory examinations. The cost of lens and screen is less than thirty dollars, and the screen can be constructed in an evening.

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# ZOOLOGY

## POLYPHYLETIC ORIGIN OF THE LEAFHOPPER FAUNA OF *ILEX DECIDUA*

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Among leafhoppers, the genus *Erythroneura* is unusual in having some 300 or more species in the Midwest. Favorite hosts for species of two large groups of *Erythroneura* are chiefly the common trees, such as oaks, hickories, beech, honey locust, alder and elms. Species of a third large group feed on grape, dogwood, redbud, and witchhazel.

In 1951, collecting at Grantsburg in southern Illinois, we found a great variety of species on a new host plant, *Ilex decidua* Walt., one of our native hollies. Analysis of this material showed that about 20 species were present in the collections, but comparison with collections made on all surrounding host species demonstrated that *Ilex* was the specific host of only four. The remainder had "drifted" onto the *Ilex* from nearby trees. Of these drifts whose host was known, three came from elm, one from maple, two from sycamore and seven from *Quercus lyrata* and *Q. palustris*. This last group from oak predominated among the drifts, undoubtedly because the two oaks were numerous in the area and their leafhopper populations abundant.

In the same area in 1952, *Erythroneura* was scarce. The same species of *Erythroneura* were found, but each was collected almost exclusively on its host tree and there was evidence of only limited drift.

At West Vienna, Ill., on the same date in 1952, we found a large colony of *Ilex decidua* with an abundance of *Erythroneura*. As in the 1951 Grantsburg collection, there was a considerable drift of elm and oak species of *Erythroneura* onto *Ilex*, chiefly species from *Quercus lyrata*.

In the first and last collections mentioned there was practically no drift of *Ilex* species to other trees. A total of eight large collections averaging about 300 specimens were made on elm, maple, and the two oaks in the two localities, and only three specimens of the total four *Ilex* species were among them. It seemed that when drift occurred there was a marked tendency for many and varied species to drift onto *Ilex*, but little for *Ilex* species to drift away from their true host.

The four *Ilex* species were *atrimucronata* Beamer, *falcata* Beamer, and *mansueta* Beamer, hitherto rare in collections, and *ilicis* n. sp. These are the first host records for *Erythroneura* in the plant family Aquifoliaceae.

Because *Ilex* is frequently associated with *Quercus lyrata* and *palustris*, it was thought at first that this tendency of the oak species to drift to *Ilex* might have some bear-

ing on the origin of the *Ilex* species, but this idea soon proved erroneous. The *Ilex* species all belong to the *obliqua* group of *Erythroneura*. The drifts from oak were principally the species *velox, knullae, gemina, gemoides, paluloides* and *richardsi,* which all belong to the *maculata* group of *Erythroneura,*and are thus only indirectly related to the *Ilex* species. The seventh oak species drift was *lyratae,* a possible close relative of an *Ilex* species, but only a single specimen was taken in the three collections on *Ilex.*

A phylogenetic analysis of the four *Ilex* leafhopper species brings out some interesting points concerning their possible origin. This analysis is based on structures of the male genitalia, which offer the best known structures to use in classifying species of *Erythroneura.* The four species of *Erythroneura* taken on *Ilex* are as follows:

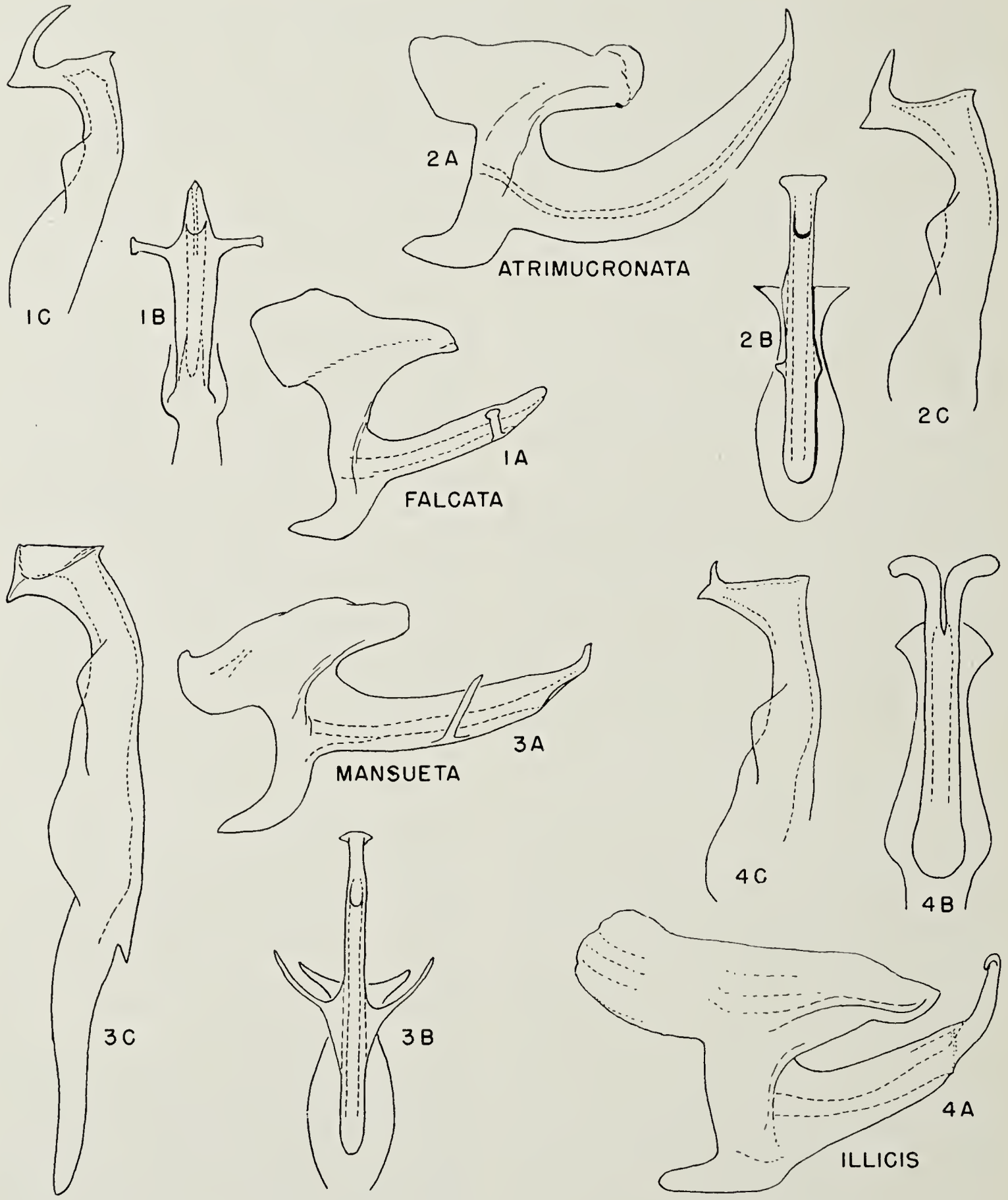
1. **Falcata** Beamer, fig. 1.—This species is the closest known relative of *cruciformis* Beamer, but is more specialized in details of structure of aedeagus and styles. *E. cruciformis* has been taken chiefly on Juglandaceae. More primitive species in the group occur on *Fagus, Acer,* and *Quercus.* It would seem that the primitive host of the group was one of these, and that *falcata,*being at the end of its line, represents a population transfer from an earlier host to *Ilex.*

2. **Atrimucronata** Beamer, fig. 2. —The shape of the aedeagus indicates that this species is a very close relative of *juglandacea* Ross, whose host is *Juglans.* It is difficult to tell which is the more primitive, although *atrimucronata* has narrow lateral flanges on the aedeagus which would indicate that it is more specialized in this character.

3. **Mansueta** Beamer, fig. 3.—There is little doubt that this species arose from a form very like *atrimucronata,* the differences in genitalia coming about by a simple filling in of the space between the posterior point and heel of the style, and the development of lateral processes on the aedeagus. *Mansueta,* however, has preserved the generalized striped pale color pattern of the *obliqua* group. On the basis of genitalia it would appear that *atrimucronata* and *mansueta* represent a pair of species that developed from a more primitive ancestor which transferred to *Ilex.* The species *juglandacea* probably arose from a segregate of the same primitive ancestor which became established on *Juglans.* As we know of no other closely related or more primitive allied forms, we cannot even hazard a guess as to the possible original host of this line. It seems certain, however, that *atrimucronata* and *mansueta* together represent a second transfer to *Ilex* independent of *falcata.*

4. **Ilicis** n. sp., fig. 4.—The deep, slender shape and peculiar apicolateral processes of the aedeagus indicate a close relationship with *victorialis* Knull (host *Vaccinium*) and *rugosae* Ross (host *Alnus*). Because of the extreme development of these characters, *ilicis* appears to be the most specialized member of this complex. It is therefore inferred that *ilicis* had its origin in a more primitive form on some other host, and that it represents a third independent population transfer to *Ilex.*

On this basis we can conclude that




FIGS. 1-4.—Male genitalia of *Erythroneura*. *A*, aedeagus, lateral aspect; *B*, aedeagus, postero-ventral aspect; *C*, style, ventro-lateral aspect.

the *Erythroneura* fauna of *Ilex decidua* includes the end products of three phyletic lines, and that each line represents an independent population transfer to *Ilex* from hosts as yet undetermined. The natural mechanism by which these host transfers occur in these leafhoppers we do not know.

Certain species new to science are reported in the above paragraphs. Their descriptions follow. Types are

deposited in the collection of the Illinois Natural History Survey.

### Obliqua Group

**Erythroneura ilicis** n. sp.

The deeply divided apex of the phalicata distinguishes this species immediately from its nearest known relative, *victorialis* Knull.

Length 3 mm. Color of body and wings coppery brown, the membrane of the wings a little darker. Male genitalia as in fig. 4. Pygofer hook evenly curved. Style with foot nearly at right angles to shaft, heel large and square, anterior and posterior points short and nearly subequal, the posterior point slightly longer and sharper. Aedeagus with very large dorsal apodeme; phalicata deep but fairly narrow, the apical portion curved dorsad and completely divided into a pair of broad lobes curved laterad.

*Holotype,* male: Grantsburg, Illinois, on *Ilex decidua,* August 31, 1951, Richards and Ross. *Allotype,* female: same data but September 23, 1952, Ross and Evers. *Paratypes*: 43 males, 39 females from Grantsburg and West Karnak, Illinois. All were taken from *Ilex decidua* Walt. except for a single male on *Acer rubrum.*

### Maculata Group

**Erythroneura paluloides** n. sp.

This species is most closely related to *immota* Beamer, but can be distinguished readily by the sharply bent dorsal aspect of the pygofer hook, fig. 5B.

Length 3.5 mm. Ground color very pale straw color, with the typical maculata group markings light orange, those on the elytron fused to make short, parallel, oblique bars. Male genitalia as in fig. 5. Lateral aspect of pygofer hook with a long narrow base and a swollen apical portion which tapers to a point; dorsal aspect sharply bent at end of base, the apical portion sinuate and roughened with minute serrations. Style with distinct heel but with anterior and posterior points reduced to mere angles. Aedeagus with small dorsal apodeme; phalicata placed high on socket, clavate, deeper than wide, and with fairly prominent serrations.

*Holotype,* male: Grantsburg, Illinois, on *Quercus palustris,* August 31, 1951, Richards and Ross. *Paratypes*: 48 males from Crab Orchard Lake, Grantsburg, Pulaski, Mermet and Metropolis, Illinois. In 1951 at Grantsburg this species constituted 10 percent of the large populations on *Quercus palustris,* with drifts on *Ilex decidua.* In 1952 at Grantsburg only a few specimens were taken, on *Quercus palustris* and *Q. lyrata.* It seems that *Quercus palustris* is the probable host, but this conclusion needs verification by additional collections.

**Erythroneura richardsi** n. sp.

Most closely related to *acantha* Ross, this species differs in its less spiculate phalicata, which is also much narrower from ventral view. In addition the apical portion of the pygofer hook is much straighter from lateral view.

Size and color similar to the preceding. Male genitalia, fig. 6, with pygofer hook long, of nearly equal thickness, and shaped as in figs. 6A and B. Style with obtuse foot, the heel and anterior point angulate, the

posterior point visible only as a minute projection. Aedeagus with phalicata situated high on socket, lateral aspect of phalicata clavate, ventral aspect slender and narrow, the apical portion bearing scattered serrations.

*Holotype,* male: Grantsburg, Illinois, on *Quercus lyrata,* August 17, 1951, Ross and Stannard. *Paratypes*: 23 males from Grantsburg and Oliver (Rocky Branch Creek), Illinois. The specimens from Grantsburg, all taken in 1951, were in about equal numbers from *Quercus palustris, Q. lyrata,* and *Ilex decidua.* None were taken the following year. Large collections from *Ilex decidua* at West Karnak in 1952 contained none, indicating a strong probability that *Ilex* is not a true host. Again, we need more collections.

**Erythroneura velox** n. sp.

The apex of the pygofer hook is the same general shape as that of *firma* Beamer and *uvaldeana* Knull, from both of which it differs in the shorter, nearly straight, and more oblique ventral arm of the apex. This difference, although comparatively slight, is exhibited perfectly by over 75 specimens from two localities.

Size and color similar to preceding, but with the orange markings much paler and in some specimens inconspicuous. Male genitalia, fig. 8, with pygofer hook divided at apex to form a short, straight dorsal projection and a longer, slightly curved, oblique ventral projection. Style with long, narrow foot, with no anterior point but with a moderately long posterior point. Aedeagus with phalicata situated high on socket; lateral aspect of phalicata regular, very slightly curved, ventral aspect regular and narrow, apical portion with a few serrations, and base with a narrow flange.

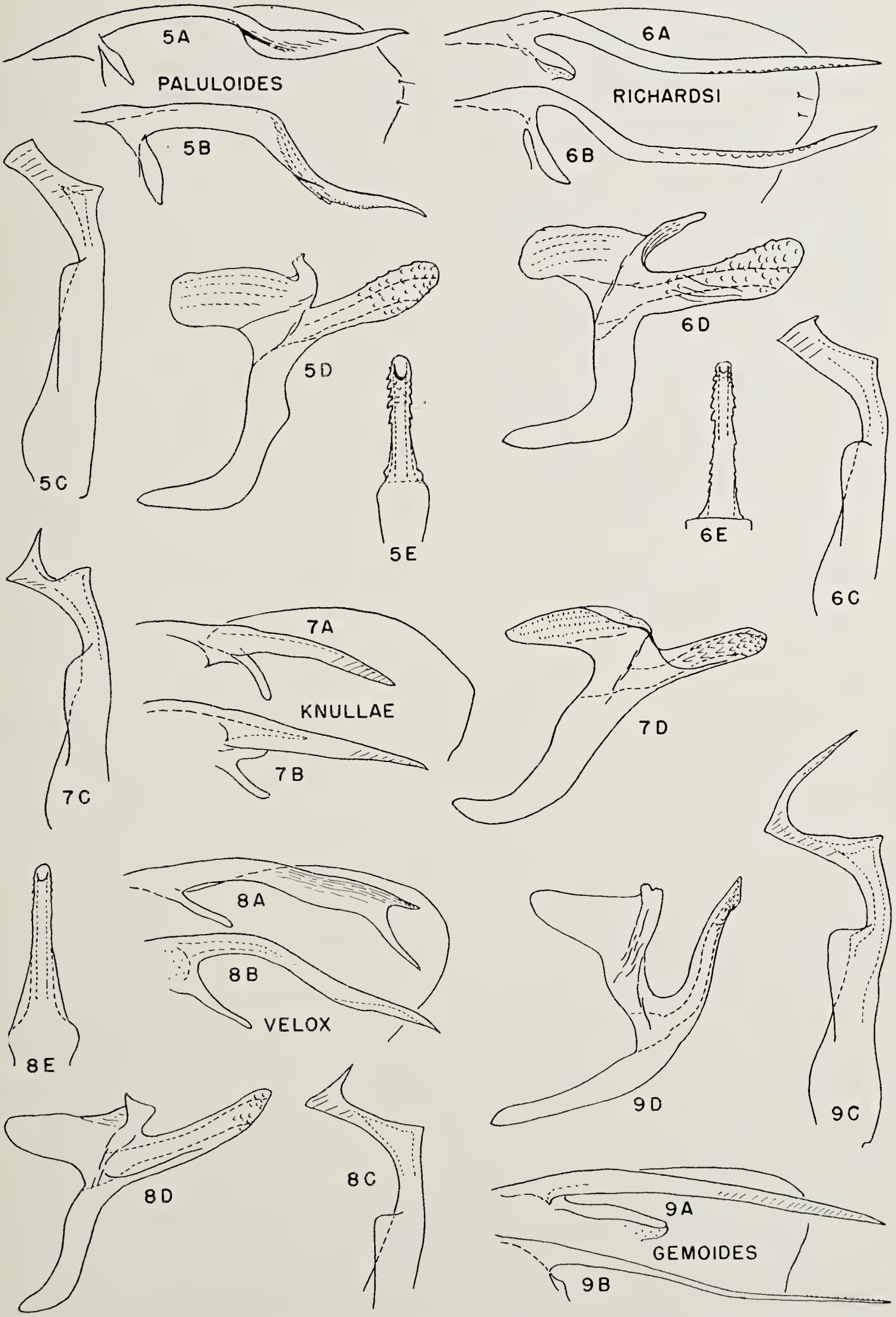
*Holotype,* male: Grantsburg, Illinois, on *Quercus lyrata,* August 28, 1952, Richards and Stannard. *Paratypes*: 81 males from Grantsburg and West Karnak, Illinois. With the exception of a few drifts on *Ilex decidua,* these were taken on *Quercus lyrata,* which is undoubtedly the preferred host.

**Erythroneura gemoides** n. sp.

This species is most closely related to *gemina* Beamer, differing primarily in the long pygofer hook which extends considerably beyond the pygofer.

Size and color similar to *paluloides* but with the elytral marks not coalesced. Male genitalia, fig. 9, with pygofer hook extending considerably beyond pygofer, lateral aspect straight and blade like, dorsal aspect thin and slightly curved. Style with elongate posterior point which is slightly longer than length of foot. Aedeagus with phalicata near ventral margin of socket; phalicata slender and slightly sinuate, with only a few serrations near apex.

*Holotype,* male: Grantsburg, Illinois, on *Quercus palustris,* August 31, 1951, Richards and Ross. *Paratypes*: 62 males from Grantsburg and northwest of Tamms, Illinois. At Grantsburg in 1951 this species constituted about 50 percent of the large populations on *Quercus palustris,* with numerous drifts on *Q. lyrata* and *Ilex decidua.* In 1952 it was confined entirely to *Quercus palustris,* indicating this species as the true host.




FIGS. 5-9.—Male genitalia of *Erythroneura*. *A*, *B*, pygofer hook, lateral and dorsal aspects, respectively; *C*, style, ventro-lateral aspect; *D*, aedeagus, lateral aspect; *E*, phalicata, postero-ventral aspect.

**Erythroneura knullae** n. sp.

This species is a close relative of *solita* Beamer, but differs in lacking the prominent sclerotized projection above the base of the phalicata.

Length 3.5 mm. Ground color whitish with typical *maculata* group spotting, in most specimens (including the holotype) these spots bright red and small. In an occasional specimen the spots are larger and paler. Male genitalia, fig. 7, with pygofer hook short, slightly curved and pointed. Style with prominent heel, and with posterior point having an unusually broad base and tapering to a sharp point. Aedeagus with phalicata near dorsal margin; lateral aspect of phalicata straight and regular, bearing moderately long serrations, ventral aspect moderately wide with lateral flanges at the base.

*Holotype,* male: Grantsburg, Illinois, on *Quercus palustris,* August 31, 1951, Richards and Ross. *Paratypes*: 46 males from Grantsburg, Dale, Metropolis and West Karnak, Illinois. These include a series of 26 males from *Quercus lyrata* at West Karnak, which indicates this as the true host. This is corroborated by the restriction of this species to the same host in the 1952 Grantsburg collections.

*Illinois Academy of Science Transactions, Vol. 46, 1953*

# ILLINOTHRIPS ROSSI, NEW GENUS AND SPECIES

## (THYSANOPTERA; PHLAEOTHRIPIDAE)

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The new species described herein occurs in central and northern Illinois. It has apparently become adapted to a colder climate, for it seems to be derived from a group of thrips generally confined to tropical or subtropical regions. This new species, *Illinothrips rossi,* resembles *Pseudocryptothrips,* a genus of warm, mild climates, and also seems to be distantly related to the *acuticornis* complex of the genus *Gastrothrips,* known from the West Indies and Yucatan. Further remarks on the relationships of *Illinothrips* will be made subsequently.

The first specimen of these thrips was captured at Elgin, Ill., in 1944 by Herbert H. Ross, for whom the species is named, and K. M. Sommerman. No others were captured until in 1951 a small series was recovered from a Berlese sample taken in Mason County located in central Illinois. Subsequent collections at Elgin have resulted in the addition of several more individuals.

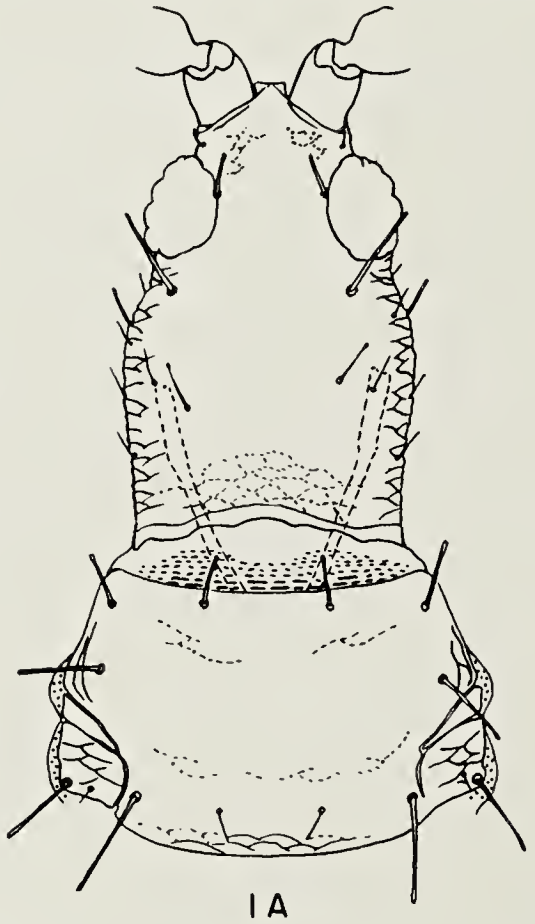
Our several collections of *rossi* were all from clumps of *Andropogon scoparius* in sites which were well drained, a gravel glacial moraine and a sand area. Almost certainly this thrips is an inhabitant of "dry" prairies as is the grass *A. scoparius.* It is possible that, in spite of our incomplete knowledge of the distribution of *rossi,* the Illinois populations are discontinuous and confined to isolated pockets. As P. W. Smith pointed out in 1951, animals with similarly restricted ranges that occur only in xeric prairies in the Illinois part of their total range may be relicts of a former warmer and drier period when the prairie peninsula was more extensive.

Sears, 1948, and Hanson & Packard, 1949, have presented some evidence that between the retreat of the last glacier and the present time there was a warmer and possibly drier period. According to Schmidt, 1938, the Illinois prairie was more extensive at one time after the last glacier than it is now. These steppe conditions may have come about during this warmer and drier time. Schmidt further suggests that the prairie peninsula and the inhabitants of this prairie spread into Illinois from the west. If the species *rossi* is indeed a relict of the prairie peninsula it is likely that the major portion of the populations will be found in areas west or southwest of Illinois, especially since the prairie has not been as reduced in the west as it has been in the east.

### **Illinothrips** new genus

**Head.**—Elongate, fig. 1*A*, with cheeks constricted behind the eyes much as in *Eurythrips,* area beyond the eyes extended slightly less than the length of the dorsal diameter of the compound eye; antenna eight-segmented, segment III subequal in length to segments I and II com-

bined, segment VIII slender, not broadly attached to segment VII; ocelli absent; compound eyes moderately developed, not as degenerate as in *Pseudocryptothrips,* fig. 2*A*, nor as in *Allothrips;* interocellar, postocular and dorso-median setae well developed; surface of head reticulate only at sides, apex and base, and then weakly so.



1A

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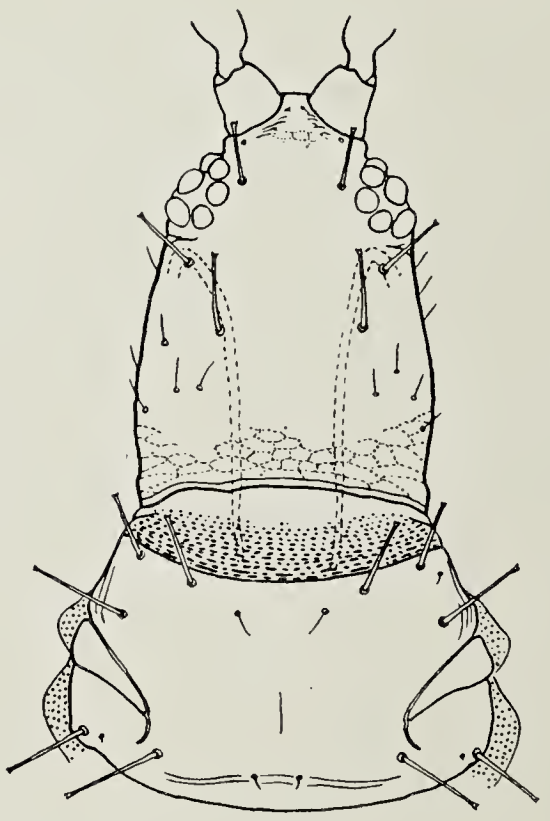

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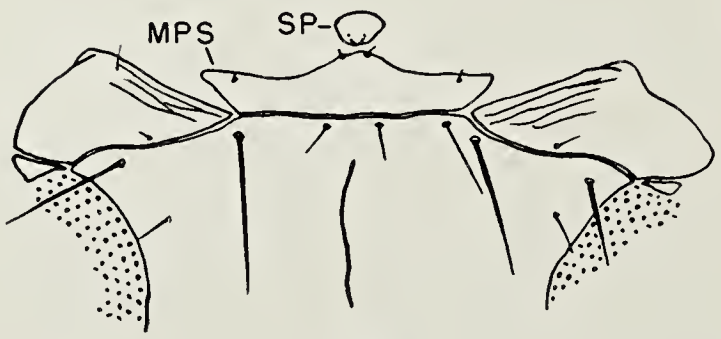


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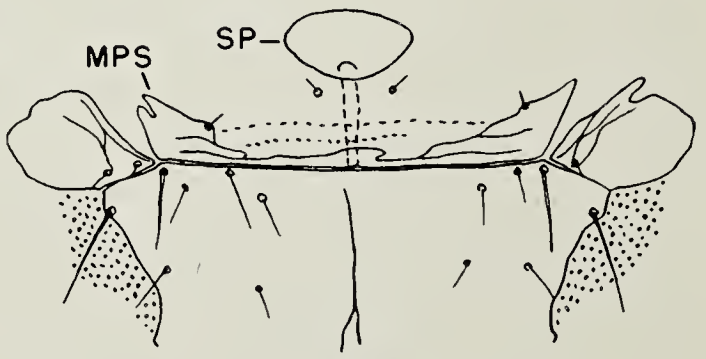


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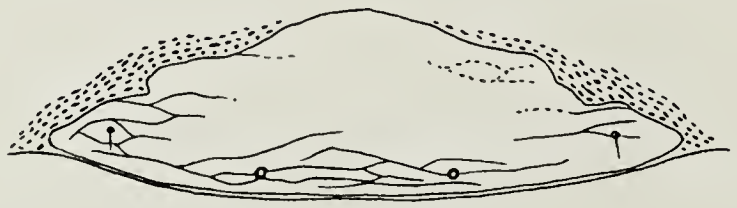

1C

2C

FIG. 1.—*Illinothrips rossi* new species. FIG. 2.—*Pseudocryptothrips* species, from Mexico.

*A*—dorsal aspect of head and prothorax; *B*—mesopraesternum (MPS) and prospinasternum (SP); *C*—pelta; *D*—right fore angle of pterothorax of male showing spine-like process arising below the mesothoracic spiracular plate.

**Mouth parts.**—Mouth cones broadly rounded; maxillary stylets thick, placed v-shaped within the head.

**Thorax.**—As in fig. 1*A*; major setae well developed, blunt at tips; praepectus developed but not large; mesopraesternum well developed, fig. 1*B*, not as extensive as in *Pseudocryptothrips,* fig. 2*B*; completely wingless, without vestiges of wing pads.

**Abdomen.**—Generally broad; pelta, fig. 1*C*; tube short but longer than median length of abdominal segment IX.

Type of genus: *Illinothrips rossi* new species.

The genus *Illinothrips* differs from representatives of *Pseudocryptothrips* in several ways. In the species of *Illinothrips* the wings are totally missing, each antennal segment VIII is slender and not broadly attached to segment VII, the mesopraesternum is well developed and small, and the pelta (the differentiated notal shield of abdominal segment I) lacks a heavy subbasal transverse ridge, compare figs. 1*C* and 2*C*. By contrast, in at least the North American species of *Pseudocryptothrips,* the wings are present as small pads, each antennal segment VIII is wide at the base and closely joined to segment VII, the mesopraesternum is more degenerate and wider, fig. 2*B*, and the pelta exhibits a heavy, transverse subbasal ridge.

In the collection of the Illinois Natural History Survey there are two male specimens of an undescribed Yucatan species, similar to *Gastrothrips aculicornis* Hood, which bear characteristics at once suggestive of males of *Illinothrips*. Both Mexican specimens bear spine-like processes on the pterothoracic fore angles just as do males of *Illinothrips*. Also this Mexican species has the antennae formed somewhat the same as in *Illinothrips,* and the mesopraesternum is small, even smaller than in *Illinothrips*. The new Mexican species of *Gastrothrips* differs most markedly in the shape of the head which is not as elongate nor as constricted behind the eyes, in the shape of the tube which is ridged, and in the shape of the pelta which is more constricted in the mid lateral region. Descriptions and illustrations of this Mexican form will be submitted for publication in the near future.

Possibly *Illinothrips* is intermediate between *Gastrothrips* and *Pseudocryptothrips*. It is more advanced than *Gastrothrips* but, by most points, it is not as specialized by degeneration as *Pseudocryptothrips*.

## **Illinothrips rossi** new species

**Female (apterous).**—Length distended exclusive of the antennae approximately 2.5 mm. Color brown and yellow. Head, legs except near base of tibiae, tip of antennal segment II and base of antennal segment III, yellowish. Pterothorax, yellowish brown. Rest of body dark brown to nearly black.

Head as in fig. 1A; antennal segment III with one sense cone located at the outer apical angle, antennal segment IV with three sense cones; prothorax as in fig. 1*B*; fore angles of pterothorax without spine-like processes; fore tarsus unarmed; pelta as in fig. 1*C*; posterior marginal setae of abdominal segment IX

not as long as tube, usually nearly ¾ the length of tube.

**Male (apterous).**—Length distended exclusive of the antennae, about 1.8 mm. Similar in general structure to the female but much lighter in color. All of body yellow except antennal segments I and IV to VIII which are brown to dark brown, being darkest in the last five segments, and the lateral posterior margins of abdominal segment VII, the posterior margins of abdominal segments VIII and IX, and the apical half of the tube which are brown to blackish brown. Each fore angle of pterothorax with a spine-like process, fig. 1*D*, fore tarsus with a moderately sized tooth.

**Holotype.**—Female; Elgin, Ill.; Aug. 1, 1944 (Ross & Sommerman); prairie hill. **Allotype.**—Male; Elgin, Ill.; Oct. 10, 1952 (Ross & Stannard); extracted by means of a Berlese funnel from clumps of *Andropogon scoparius*. **Paratypes.**—1 female; same data as for allotype. 10 females, 4 males; Bath, Ill.; Oct. 2, 1951 (Sanderson & Stannard); from clumps of *Andropogon*.

The types of this species have been deposited in the collections of the Illinois Natural History Survey.

The holotype female, captured in August, contained two well developed eggs within the abdomen whereas those collected in October showed no evidence of egg production. It is possible that this species terminates reproduction in late summer and that the resultant larvae mature in October. The winter may be passed in the adult stage. One teneral female was found in the early October collection taken at Bath, Ill., indicating the probability that adults of that season were newly transformed. Considering the absence of eggs in October and the closeness of the approach of cold weather it is reasonable to suppose that it is the young adults and not the larvae nor the eggs that overwinter. Most likely reproduction occurs in spring as well as later in summer.

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# THE UNITY OF ANIMAL POPULATIONS

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For many years now there have been appearing in the biological literature references to the actions of groups of organisms reminiscent of the actions of individual animals. A basic philosophy running through these discourses is the subordination of the individual of a species and the consideration of it only as it contributes to the existence of the species.

The subordination of the individual to the group, the contribution in a specialized way of the individual to the group, has given rise to the concept of the supra-organism. This concept analogizes population activities with those of an individual organism. Depending on the field of interest of the investigator, or his bias in thought, the definition of the supra-organism varies and becomes inclusive or restrictive. To some ecologists it is the ecological community. Therefore it consists of many species living together under broad restrictions. To some entomologists it is limited to insects which display a social structure. Emerson (1952), while not defining the supra-organism, defines the organism and thus gives us a base for analogy with attributes of groups of individuals. According to Emerson an organism possesses, among others, the following characteristics:

(1) It is an open system importing and exporting component materials and energy, and exhibiting orientation in space.

(2) It maintains a relatively steady state as a unit system. There is a tendency toward dynamic equilibrium, balance, periodicity, and self-regulation.

(3) It performs specific synthesis of its substance and repeats or duplicates its pattern.

(4) It exhibits division of labor in its parts, and integration of the whole.

(5) It has a temporal ontogeny and a temporal phylogeny.

Activities of nonsocial animals have not generally been considered as analogizing with the activities of an organism, but it appears that such analogies do exist.

If one attempts to find evidence of supra-organismic activity among nonsocial organisms, one must broaden his concept of division of labor or discard it. One must also question highly developed social or ecological integration as a criterion. Supra-organism analogies are most easily discovered among the higher social forms, but do they exist among lower social orders? One cannot eliminate division of labor completely from any bisexual species for bisexuality in itself is a division of labor. Nor can one divorce it from species which care for their young. Adults perform the functions of protection and provide for nutrition of the young. This is especially apparent in altricial forms.

If we take Emerson's definition of a multicellular organism as a start-

ing point, we may look for analogies with lower social units or even nonsocial species.

1. *An organism is an open system importing and exporting component materials and energy, and exhibiting orientation in space.*—I do not at this time analogize activities of diffuse populations with the nutritional activities of an organism. However, in exhibiting orientation in space we find parallels which may be of value. Migratory animals have a high degree of orientation. As surely as an individual may orient itself in relation to external stimuli, a flock of yellow warblers or golden plover orient themselves. With individuals this orientation expresses itself in various, often obvious, tropisms. The causes bringing about the orientation effects in diffuse populations are not so well understood.

The more highly migratory species often follow certain temperature movements but studies such as those of Rowan (1925) and others have cast doubt on temperature as a motivating factor. Day length has a profound effect on the physiology of migratory birds, and this effect may initiate migratory orientation. But this orientation is probably the result of a chain of factors, and we are far from unraveling the causes and their interrelationships at this time. Unidirectional, nonreturning migrations may have still other initiating causes. Why does the thistle butterfly indulge in these movements? Why will bands of mormon crickets or beet webworms move in one direction, often without dissipating food supplies through which they pass? Why are there mass movements of tree squirrels? Of lemmings? Complete utilization of a food supply or some essential part of a food supply might initiate movement, but there is evidence in muskrats that a high population is a restless one. Perhaps in some forms there is a minimum spatial limitation which, when reached, sets up psychic disturbances which in turn release a unidirectional movement.

2. *An organism maintains a relatively steady state as a unit system. There is a tendency toward dynamic equilibrium, balance, periodicity, and self regulation.*—Perhaps the most important attribute of nonsocial populations is their tendency, which almost amounts to an obsession, to be regulated in size. Much of this regulation is self-induced by the population. Cannibalism in closed cultures of *Tribolium* is a self-regulating mechanism. Intraspecific intolerance among muskrats or upland game birds is self-regulatory. Dissipation of a food supply is self-regulatory. Territoriality and consequent spacing is self-regulatory. That populations of nonsocial animals are held stable is one of the most consistent phenomena in nature. A population may in successive generations have a potential of increasing from 2 to 200 to 20,000 to 2,000,000. Instead it progresses from generation to generation possibly as 2 to 1.9 to 2.2 to 2.1 to 1.8 to 2.0. This stabilization in size is parallel to the stabilization, the "steady state as a unit system," of an organism. And much of this steadiness is directly or indirectly self-induced.

The phenomenon of inverse ratios is a conspicuous example of self-regulation. By inverse ratios we

mean that as the breeding population increases there is an inversity in the success of the breeding. Several dramatic examples can be given. Errington (1942) has described one as follows:

> On roughly one-half of the marsh, losses (to muskrats) from causes other than intraspecific strife were not great but breeding stopped by midsummer.. ..On the other half, losses through disease and predation predominated, . . . and nearly all of the late summer litters —usually the third and fourth of the season for individual females—were born on sections of the marsh where known early-summer mortality of the young had been highest.

Allen (1943) has shown that, after a population of squirrels with a known breeding pattern had suffered decimation through loss of food supply, a higher percentage of females became pregnant and young squirrels started breeding three months before their normal time. The New York grouse study (Bump, et al, 1947) reports that where low densities of ruffed grouse occurred young were produced in greater numbers.

Periodicity in nonsocial populations has long been the subject of surmise and study. Much time could be spent discussing the ups and downs of populations which seem to recur at rather regular intervals. There is the so-called ten-year game cycle. Ruffed grouse seem to fluctuate at about ten-year intervals, the varying hare from 8-11, etc. Siivonen (1948) has recently postulated a cycle of about 3⅓ years for several animals, each third peak being larger and representing the 10-year period. Hamilton (1937) has seen a cycle in meadow mice of approximately 4 years. There is much contradicting as well as corroborating evidence concerning this cycle; Cole (1951), however, believes that a series of random numbers will show fluctuations of about the same amplitude as those seen in nature.

Contradictory data are to be expected, for much of our information on cycles is based on gross numbers, which may be quite misleading. There are two sets of factors which will produce variations in numbers. One set consists of external factors which will affect populations after birth or hatching. The other set affects populations by varying the numbers which are produced for the first set to work on. Gross numbers are the results of the combined actions of both sets and are therefore polyvalent. True cyclic behavior may be masked in part or in the whole by this nonsegregation of causations. Storms, disease, and the like are illustrations of the first set, and differences in ovulation or in susceptibility to disease are examples of the second. Until we are able to differentiate between these internal and external factors, between the true and pseudo cycle, there will be contradictory data. In spite of this there does appear to be some sort of population periodicity analogous to physiological periodicity in the individual.

3. *An organism performs specific syntheses of its substances and repeats or duplicates its patterns.*—As far as my thinking has gone, it appears that a specific synthesis of materials is not paralleled in nonsocial populations. However, such populations duplicate their pattern from year to year and from area to area. Population expressions such as host predilection or migratory pattern are carried over from one gener-

ation to another. The English sparrow has the same habits, the same loquacity, the same nests, in America and in Europe. A small colony which I observed at Camaguay, Cuba, was still unmistakably sparrow-like in its habits. Norway rats are Norway rats all over the world, whether in Illinois or on an isolated Pacific island. The pattern is duplicated.

4. *An organism exhibits division of labor in its parts and integration of the whole.*—We have already noted that bisexuality, which is universal in the higher vertebrates, can be construed as an expression of division of labor in a primitive sense. In some species this goes beyond the division of the sexual responsibilities. The hornbill female lays its eggs in a hollow trunk and incubates them. The male plasters the opening shut with mud, leaving a small aperture through which it feeds the female. At hatching time the closure is removed.

There are interesting variations from the normal pattern. The case of the phalaropes is classical: the usual plumage pattern is reversed, the male being the modestly clothed sex and the female relieving herself of household duties after oviposition, which duties devolve on the male. This is true to a lesser extent among other shore birds. Certain birds are communistic—the smooth billed ani, for example—in that the females lay eggs in a communal nest.

What may not quite be a division of labor but an assumption of responsibility by the parents on a temporary basis is often seen. The feeding and protection of altricial young, and the protection of precocial young are examples. The alleged "watchman function" of certain individuals in flocking birds or herding mammals would be a primitive division of labor. And in colonial hydroids, which are certainly not social in the accepted sense, there is a continuity of nutrition but a strong division of labor among different organisms in the same colony.

Demands of a rather constant nature on a population may be met by some individuals in the population, thus satisfying the levy and protecting the remaining population. Compensatory loss may express this phenomenon. Where a carrying capacity is evident in an environment, a population may be pinched down in one or several of many ways. Disease, predation, emigration with consequent increased hazard, climatic extremes—all may play a part in wiping out a surplus. Even within one loss-producing mechanism this compensation may be seen. When one predator does not assess the usual tax, possibly through reduction in numbers of the predator or a new protective device on the part of the prey, other species not commonly considered as predatory on the host take over the function. In New York the destruction of the common predators attacking ruffed grouse brought on attacks by pine squirrels (Bump, et al, 1947). In Illinois we have noted that protection of wood ducks from raccoons, snakes, and squirrels was accompanied by nest destruction by woodpeckers.

5. *An organism has a temporal ontogeny and a temporal phylogeny.*—All populations, whether they be social or nonsocial, go through waxing and waning periods. They have

a development and a senescence. Bodenheimer (1937) has said that the growth of colonies of social insects may be divided into three periods: (1) the initial period of colony foundation, (2) the period of expansion and vigor, and (3) the period of senescence and death. "The growth of these colonies resembles that of organisms." In looking for analogies with diffuse, nonsocial populations we must extend time greatly over that which concerns us in the colony cycle. In organisms introduced into new areas it is easy to see the growth of populations and the invasion of ecologically acceptable habitats. The origin of new populations at the species level (or above) is characterized by expenditure of time in units which extend beyond the time which has yet been expended in scientific endeavor. However, methods in nature have been postulated and there are reasonably creditable theories.

It is much easier to note senescence and decay during our period of scientific thought and observation. Many species have disappeared, some of them without the direct intervention of man insofar as we know. The Labrador duck disappeared before gunning for waterfowl was a factor, and it was not esteemed as food. The large coastal mink of the north Atlantic possibly suffered a somewhat similar fate. Ground sloths and the native elephants disappeared before recorded history but after the appearance of man in North America. That the California condor may be on its way to oblivion is indicated by the records of an earlier wide distribution. It would appear, then, that there is a process analogous to the ontogeny of the individual at work among species.

Reversing the usual procedure of defining terms in advance, we can now define the supra-organism, in the sense used above, as follows:

> A supra-organism is a population of organisms of the same species which as a unit carries out some functions analogous to those of an individual.

The concept of the supra-organism is in its infancy. It has, possibly, caught up with its food supply and must wait for continued growth until it can be nourished by future discoveries to be made in the population dynamics of a wide variety of animals. It may have considerable value in the future in elucidating and allowing prediction of activities of populations, in predicting what certain variations of population treatment will do. It may, for example, be a philosophical tool of high importance in economic entomology or in fish and game management.

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# FACTORS INFLUENCING THE PACKED CELL VOLUME OF FROG BLOOD

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At least three measurements are necessary to determine the condition of the red blood cells in health and disease. These are the red cell count, the hemoglobin concentration, and the red (packed) cell volume.

Information concerning the packed cell volume (PCV) of frog blood is available in the literature (1, 2,), but only a numerical normal value is given, and nothing is said about the factors which may influence the stated figures. In order to use the packed cell volume as a valid criterion in the study of the blood, an evaluation of the factors which may significantly influence the measurements is essential. The present study analyzes the effect of factors usually encountered in the laboratory upon the experimentally determined value of the PCV in frog blood.

## Materials and Methods

Male and female frogs of the species *Rana pipiens* were used in most cases. In some trials *Rana clamitans* was employed. No differences in PCV were observed between the species.

Blood was collected only from the heart because of the reported difference in some animals between cardiac and peripheral blood (3). Care was exercised to avoid admixture of the blood sample with tissue fluid; this fluid tended to be amassed, particularly in the female during the egg-laying period, and was often evidenced by adhesions between the pericardial sac and the body wall. The fluid may inordinately reduce values and should be guarded against.

The 10 mm. Wintrobe hematocrit tube was used. The anticoagulant, 3 percent sodium citrate, was first added to the 1 mm. graduation. As much blood as possible was collected. Whereas in the early experiments only enough blood was obtained to fill approximately one-half the height of the tube (an average of 4.5 mm. in the first 126 healthy frogs), proficiency in technic later permitted filling to an average of approximately two-thirds of the tube. The resulting error (discussed later in experimental data) is very small. The centrifuge was run at 2600 r.p.m. for at least thirty minutes. The PCV was determined in percent from the proportion: packed cell level/total level = packed cell volume/100.

The factors considered included sex, red leg disease, gravidity, environmental temperature, volume of blood used, duration of centrifugation, and anesthesia. The presence of real differences from the normal was tested by statistical analysis of the data.

Frogs were considered to have red leg disease when they showed gross signs and bodily symptoms of a hemorrhagic septicemia, and when the blood smear revealed the presence of

the causative organism (4). In addition to frogs with naturally contracted red leg, frogs which contracted the disease by bacterial injection were used. Cultures of *Pseudomonas hydrophila,* from the American Type Culture Collection, serial number 9071, were inoculated daily on fresh slants of Difco brain-heart agar and incubated at 37° C. for 24 hours. The slants were washed with 5 ml. of sterile physiological saline solution and a 1:1,000 dilution made, one ml. of which was injected. Blood smears treated with Wright's stain showed the presence of bacterial invasion of the red blood cells of diseased frogs.

In the usual procedure, after the frogs had been removed from storage in the refrigerator and kept at room temperature for 30 minutes, they were rendered unconscious by a sharp blow on the head, and the blood sample was then taken. To study the influence of temperature upon PCV, blood samples were collected from frogs immediately upon their removal from the refrigerator, where they had been kept at 6° C. To study the influence of anesthesia, blood samples were taken from frogs which had been anesthetized with ether.

## Experimental Data

The possibility of a sex difference in PCV was checked by a comparison of 304 healthy males with 233 healthy females. A highly significant sex difference was apparent.

The packed cell volume was significantly altered from the normal value in frogs with red leg disease.

Table 1.—Factors Influencing the Packed Cell Volume of Frog Blood

| Factor studied | Number of animals | Mean PCV (in percent) | Standard deviation of mean | t value |
|---|---|---|---|---|
| Sex differences in normal frogs | 304 male | 30.04 | 7.69 | |
| | 233 female | 24.77 | 7.42 | 8.0 |
| PCV for healthy non-gravid females vs. PCV for healthy gravid females | 76 non-gravid | 23.52 | 7.39 | |
| | 102 gravid | 25.52 | 7.49 | 1.75 |
| Influence of disease on PCV | | | | |
| Normal vs. red leg | 585 normal | 27.87 | 7.74 | |
| (Mixture of sexes) | 185 diseased | 25.35 | 9.56 | 3.64 |
| PCV for naturally acquired red leg vs. PCV for injected red leg | 128 natural | 25.98 | 9.73 | |
| (Mixture of sexes) | 57 injected | 23.95 | 8.29 | 1.37 |
| Frogs at room temperature vs. frogs adapted to 6°C | 419 at room temp. | 27.08 | 7.77 | |
| | 48 at 6°C. | 29.18 | 4.90 | 1.84 |
| PCV in normal males vs. PCV in anesthetized males | 304 normal | 30.04 | 7.69 | |
| | 100 etherized | 30.40 | 8.46 | 0.39 |

A total of 585 normal frogs were compared with 185 diseased frogs. There was no difference between frogs which had contracted red leg disease naturally and those which had contracted the disease artificially by injection of *P. hydrophila*.

There was no real difference in PCV between gravid and nongravid females. No special precaution in this regard need be taken in collecting blood samples from females.

The temperature of the cold environment (about 6° C.) in which the frogs were stored did not appreciably influence the value of the PCV. Frogs kept one-half hour to several hours at room temperature showed no real differences in PCV.

Ether anesthesia in 100 etherized frogs gave values for the PCV which were not essentially different from those obtained in 304 unanesthetized frogs.

All the above data are summarized in table 1.

In addition to the above constitutional and environmental factors which are commonly encountered in laboratory practice, errors known in other animals to be due to experimental procedure were reexamined in the frog.

Figure 1 shows that PCV depends upon duration of centrifugation and upon the volume of the blood sample. With the speed held constant at 2600 r.p.m., there was no change in PCV after centrifuging for 20 minutes.

A larger volume of blood yielded greater PCV values throughout the range tested. At the end of 45 minutes, a single 0.857 cc. sample of blood gave a PCV of 37.51 percent; another sample of 0.325 cc., from the same frog, gave a PCV of 34.46 percent.

A more typical picture in an average healthy group of frogs was then sought. A series of trials in ten male frogs, in which the blood sample filled the Wintrobe tube to the 10 mm. mark, gave a mean PCV value of 35.9 percent, whereas in another ten frogs the experimental mean for a 4.5 mm. column of blood was 34.0 percent. In order to completely eliminate this source of error in an animal as small as the frog, the alternatives are the use of pooled bloods or substitution with a micromethod involving capillary blood. The latter technic was tried and found to be unreliable. For most of the data presented herein, the average sample height attained was approximately 7.5 mm.

## Discussion

The packed cell volume appears to be a fairly stable factor which resists many internal bodily and external environmental influences.

Sex is a constitutional factor which exerts a most marked influence on the PCV of frog blood. The PCV of the males is about 6 percent higher than that of the females. This agency must be considered in presenting hematologic data for the PCV in frogs. A similar sex difference has been established by the senior author (5) for red blood cell counts and hemoglobin percentages in frogs.

The discovery of a sex difference in frog hematocrit data is novel and unexpected. Schnitter (6) claims that there are no hematocrit differences in human beings resulting directly from sex. We are now in-

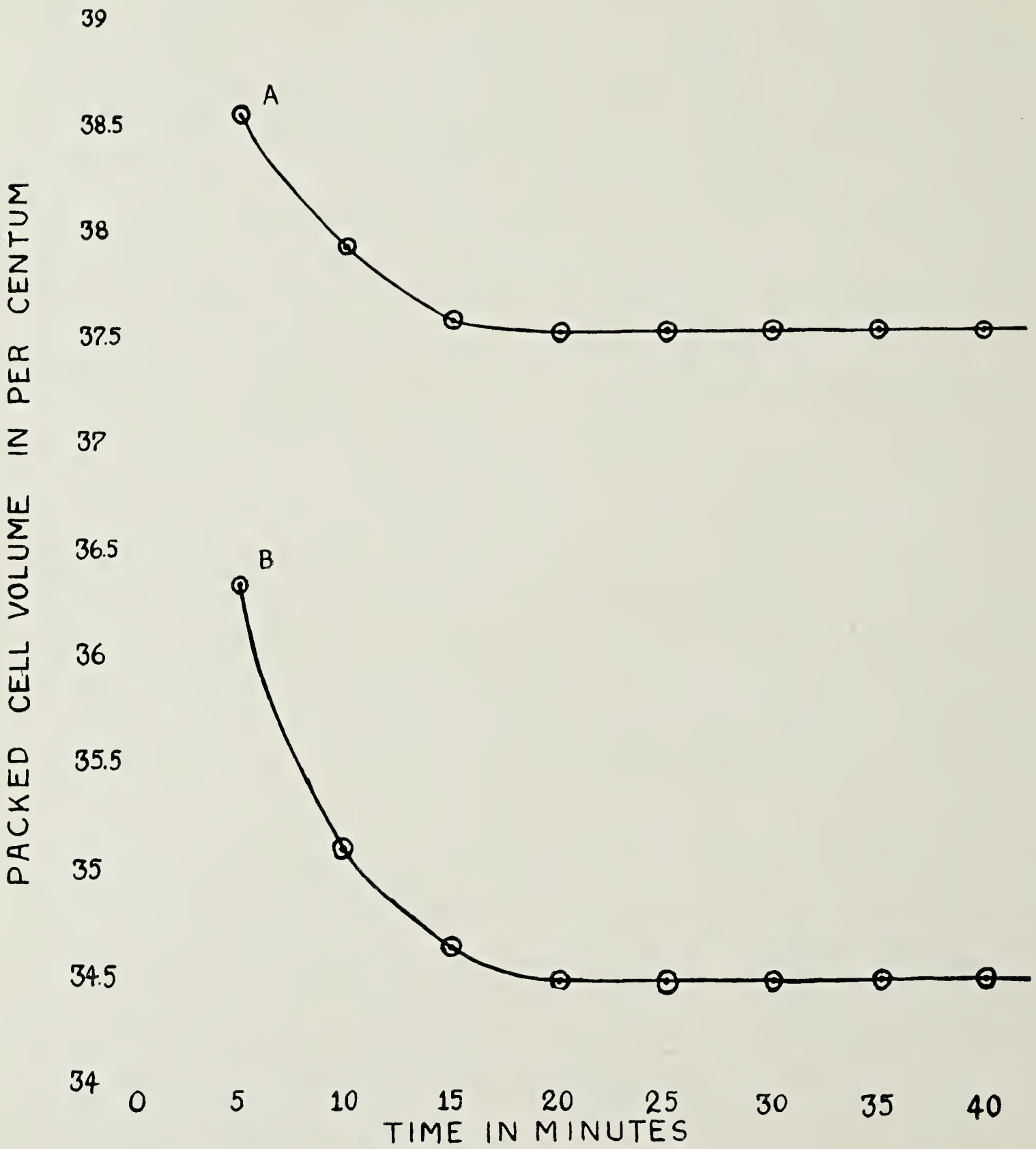


FIG. I - CURVE A IS A .857 CC. SAMPLE OF FROG BLOOD.
CURVE B IS A .325 CC. SAMPLE OF FROG BLOOD FROM THE SAME SPECIMEN AS USED IN CURVE A.

vestigating this situation more fully by examining the packed cell volumes of several other vertebrates.

There is a significant difference between the PCV of healthy frogs and those with red leg disease. Efforts were made to use animals which were all in the same advanced stage of the disease, but there were probably variations in the severity of the infection. This could reduce the expression of maximal differences from the normal condition.

Etherization produces no immediate effect on the PCV.

In man, it is considered inadvisable to take blood samples for determination of the PCV for about 24 hours after etherization. Hausner et al. (7) state that in dogs, ether pro-

duces constriction of the spleen and increases the number of erythrocytes in the blood. We were not concerned in the frog about the delayed effects of ether on the blood. The blood does darken in the etherized frog, suggesting hemoconcentration. No conclusions concerning the immediate effects of anesthetics other than ether should be drawn from these data.

## Summary

The manner in which the packed cell volume of frog blood may be significantly altered by various factors has been presented. Sex appeared to be the greatest factor in normal frogs. There was a significant difference between the PCV of diseased and normal frogs. Animals acquiring red leg disease in nature had essentially the same packed cell volumes as frogs inoculated with red leg organisms. Ether anesthesia in healthy animals caused no immediate changes in the PCV. Gravidity and environmental temperature did not affect the PCV to any real extent. Both the volume of the blood sample and the time of centrifugation had a marked effect upon the value of the PCV.

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# LAND-SNAIL SHELLS FOUND IN A KITCHEN MIDDEN OF ILLINOIAN INDIANS OF THE HOPEWELL CULTURE

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References to the shells of snails which have been associated with Indian culture of the past in Illinois are limited. Probably Frank C. Baker, who was formerly curator of the University of Illinois Museum of Natural History, has discussed them most thoroughly from the zoological aspect (1930, 1931). From collections which he had received from the Cahokia and Havana mounds, he found the aquatic forms, *Campeloma, Anculosa, Lymnaea,* and *Planorbis* (*Helisoma*). Although he assumed that they had been used as food, he presented no evidence to verify this statement. He also observed that land-snails were seldom found in mounds and that there was no indication that they had been used as food. Although his contribution was quantitative to the extent that he enumerated the various classes of mollusks which were found in the mounds, he made no attempt to establish the frequency of the various species of land-snails or bivalves which were present.

Recently, the author has been given several large collections of unionids (fresh-water mussels) and gastropods (snails) which had been removed from various Indian sites by John McGregor, Professor of Anthropology, University of Illinois. The sites were in southwestern Illinois near the Illinois and Mississippi Rivers. Up to the present, the shells found in a village which existed about 500 B.C. on McGee's Creek, a small stream flowing into the Illinois River below Meredosia, have been analyzed. This site was given priority because it seemed to represent a well established Indian community, according to the artifacts and other items obtained by Dr. McGregor and his helpers. An analysis of the unionid shells, along with a description of the creek as it must have formerly appeared when the mussels were living, has already been completed (Matteson, 1953).

The site is located on the Robert Poole farm in Chambersburg township (at north edge Sec. 5, T. 2 S., R. 2 W.). The former village contained one dwelling of considerable size which is located about forty feet from the present bank of the creek. Although broken pottery, gardening utensils, other artifacts, and the valves of mussels were found scattered throughout the village, most of the shells of mussels and land-snails were found in one compact kitchen midden located in the field back of the village.

The midden was first noticed by Mr. Poole after he had plowed up several valves of fresh-water mussels. Further examination revealed that the mass of shells extended into the ground for a considerable distance. Broken artifacts, individual beads and other items cast off by the In-

dians were present although little soil was mixed with the shells. The shells of land-snails were scattered throughout the mass. It was noticed that they were more concentrated at its surface. The remains of no aquatic snails were found. This is an interesting fact because aquatic snails were present in a midden located at another site less than a mile farther down the creek where a village had existed more recently, and at another site near its mouth which had been occupied by Indians about 5000 years ago.

An analysis of the land-snail shells revealed two genera which were represented by six species. All corresponded to the descriptions set forth by Pilsbry (1940, 1948). There is a chance that the shells of smaller land-snails might have been present but were either undiscovered during excavation or had disintegrated due to the effects of time. The following varieties were identified:

*Allogona profunda* (Say) (17)
*Anguispira alternata* (Say) (36)
*Anguispira kochi* (Pfeiffer) (31)
*Mesodon clausus* (Say) (2)
*Mesodon pennsylvanicus* (Green) (2)
*Mesodon thyroidus* (Say) (17)

As the snail-shells were mixed with mussel valves, both Dr. McGregor and the author first assumed that the Indians used land-snails, as well as fresh-water mussels, as food. Soon, divergence of opinion occurred, with the former continuing to believe that they were an item of diet. It was decided that the friendly argument should continue further in order that a logical conclusion might be made.

With few exceptions, the shells have been preserved in excellent condition. The color patterns of *A. alternata*, *A. kochi*, and *A. profunda* are still clear (Fig. 1). However, many of the mussel valves were badly decomposed. The shells of aquatic snails previously mentioned as being discovered at another Indian site of more recent origin were also in poor condition. No differences in composition can be noticed between the shells of living terrestrial and aquatic pulmonates. Furthermore, the heavier shells of the aquatic operculates should have been found in better condition than those in question. One is led to believe that the shells of land-snails are no better equipped than the aquatic forms to resist the effects of weathering while underground during long periods. These facts imply that the terrestrial snails from this site must be of comparatively recent origin.

All snails require substantial amounts of calcium carbonate in order that the shell may be developed satisfactorily. A piece of chalk thrown into an aquarium occupied by aquatic snails soon becomes covered by them. Living terrestrial snails will devour the shells of dead companions, and some varieties, including the genus *Anguispira*, will actually eat the shells of other living snails.

A land-snail's affinity for shell-forming material may explain the presence of the snails in the kitchen midden. They probably began wandering onto the refuse pile when it was first formed by the Indians. Many remained for an extended period of time and some of them died there. In the meantime, more discarded valves of unionids were added to the pile, covering both the previous valves and snail-shells. In time, the midden assumed its final

FIG. 1.—Shells of land-snails found in a kitchen midden located near McGee's Creek, Chambersburg Township, Illinois. First row (left to right): 1-2 *Mesodon thyroidus;* 3-4 *M. clausus;* 5-6 *M. pennsylvanicus.* Second and third rows: *Allogona profunda.* Fourth and fifth rows: *Anguispira kochi.* Sixth and seventh rows: *Anguispira alternata.*

shape and was composed mainly of mussel shells interspersed with terrestrial snail-shells. As the surface of the pile was exposed for many years, a higher concentration of snail-shells was present there.

The lip which surrounds the aperture of each shell is usually intact. If the soft parts had been used as food, the lip would have been de-

stroyed during the process of removing the body from the shell. Dr. McGregor has suggested that as boiling was employed in the preparation of certain foods by the Indians of that period, the snails were first treated in this manner which facilitated the removal of the meat from the shell. However, the body of a snail contracts farther into the shell when it is placed in hot water. Without the use of some utensil comparable with modern forceps, the body still could not be removed without breaking the shell. The logical way by which an Indian could have removed the boiled soft part is to crush the rather frail shell between the thumb and index finger.

The Indian may have had some device, not yet discovered, by which he extracted the edible parts of the snail from the shell. A former resident of Hawaii relates that the natives there place snails on rocks which are then slowly heated. The bodies of the snails gradually relax and eventually protrude from the shells at the time of death. After further heating, each soft part is torn from its shell and eaten. However, an analysis of available evidence shows that land-snails were not an item of diet of the Indians at the site mentioned herein. They became a part of the kitchen midden while seeking food. Some of them probably have died there within the last century.

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# ZOOGEOGRAPHICAL RELATIONSHIPS OF THE MAMMALS OF ILLINOIS

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Fifty-four species of native mammals are found at the present time in Illinois. Some of these species are principally southern mammals whose range barely extends into Illinois. Still other species are western, eastern, or northern. However, most of the species of mammals in Illinois are wide-ranging or cosmopolitan species, occurring in all or most of the states surrounding Illinois, and do not reach their limits of distribution within Illinois.

The distribution patterns of the mammals found in Illinois indicate that 65 percent or 35 species are wide-ranging or cosmopolitan (fig. 1). Of these 35 species, four are predominantly southern in distribution, two predominantly northern, and one western. None are eastern. The remaining 19 species show the following relationships:

| *Principal Area* | *No. of species* | *Percent* |
|---|---|---|
| Western and northwestern | 7 | 37 |
| Southern and southeastern | 8 | 42 |
| Northern ..... | 4 | 21 |

*Western species of mammals entering Illinois*

Western big-eared bat (*Corynorhinus rafinesquii*) (S)[1]

Badger (*Taxidea taxus*) (N)

Coyote (*Canis latrans*) (E)

13-lined ground squirrel (*Citellus tridecemlineatus*) (N, E)

Plains pocket gopher (*Geomys bursarius*)

White-tailed jackrabbit (*Lepus townsendii*) (N)

*Northwestern species of mammals entering Illinois*

Franklin ground squirrel (*Citellus franklinii*)

*Southern species of mammals entering Illinois*

Gray myotis (*Myotis grisescens*)

Golden mouse (*Peromyscus nuttalli*)

Cotton mouse (*Peromyscus gossypinus*)

Eastern woodrat (*Neotoma floridana*) (W, E)

Swamp rabbit (*Sylvilagus aquaticus*)

*Southeastern species of mammals entering Illinois*

Southeastern shrew (*Sorex longirostris*)

Indiana myotis (*Myotis sodalis*) (E)

Rice rat (*Oryzomys palustris*)

*Northern species of mammals entering Illinois*

Masked shrew (*Sorex cinereus*)

Pigmy shrew (*Microsorex hoyi*)

Least weasel (*Mustela rixosa*)

Meadow vole (*Microtus pennsylvanicus*) (W, E)

Analysis of these facts indicates that the state of Illinois does not represent the distributional limit for most species occurring therein. Only about 35 percent of the species are essentially not mid-United States in

[1] "S" indicates that the species occurs also to the south; "N," north; "E," east; "W," west.

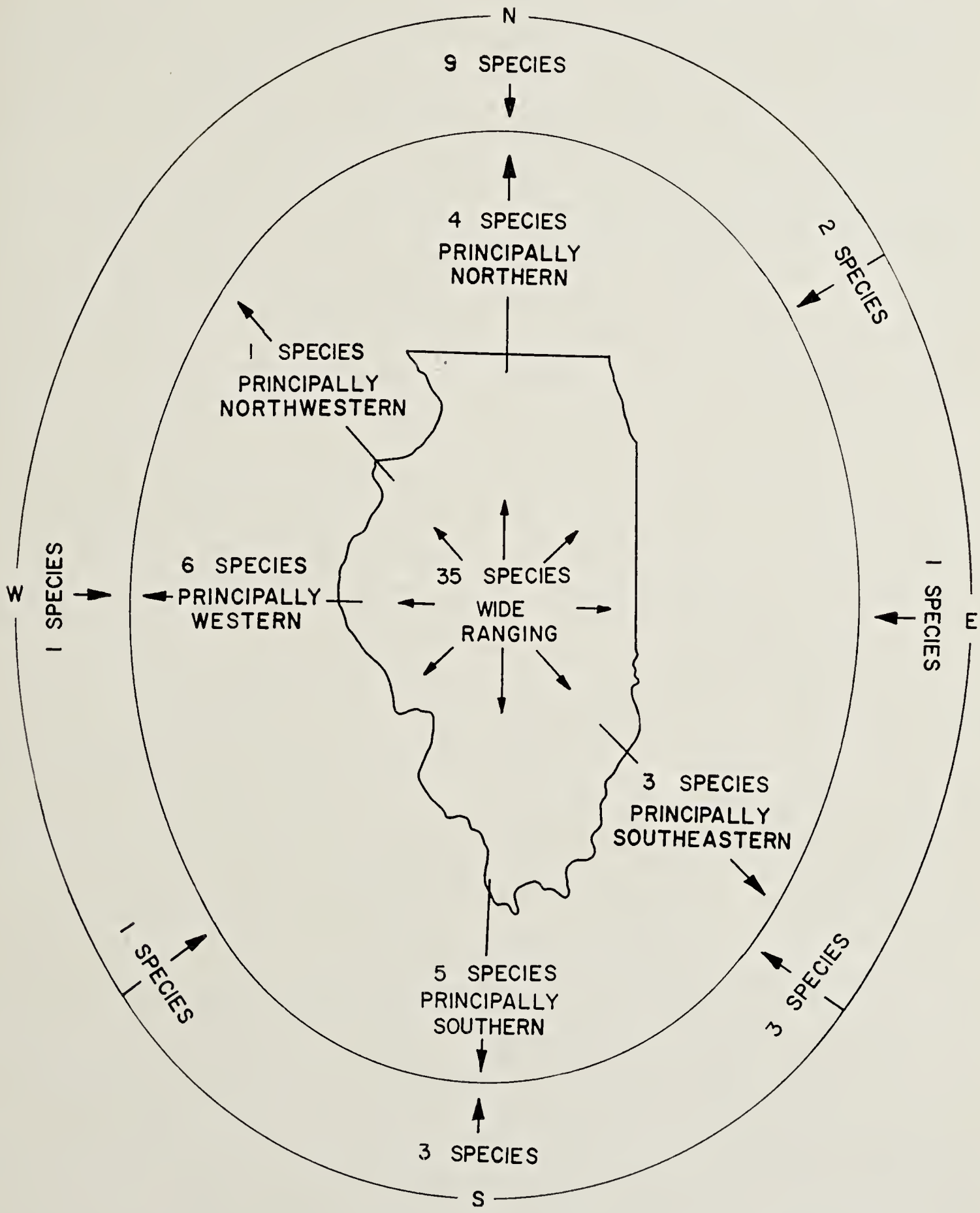


FIG. 1.—The geographical relationships of the 54 species of Illinois mammals are shown within the inner circle: 35 species are wide-ranging; the 19 other species are characteristic of some region outside Illinois. The outer circle indicates that 20 species are found in states adjacent to but not in Illinois.

distribution. Of these, nearly all are western (and northwestern) and southern (and southeastern). None is considered an eastern species that reaches its western limit in Illinois, and only four are northern species.

The abundance of western species is correlated with the invasion of western prairie conditions into parts of Illinois. The abundance of southern species is correlated with the presence in southernmost Illinois of swamps and thickets of a southern type (cypress, gum, etc.). The Ozark Hills of southern Illinois do not provide habitat for any mammals characteristic of the Ozarks to the southwest, but if red wolves occurred in the Ozark Hills in former times, this species would be one such example. The Ozark Hills probably present a barrier to the northward spread of some southern species.

Many species of mammals occur in adjacent states but do not enter Illinois (fig. 1). Half of these are northern species that reach their southern limit in Wisconsin. Nearly all southern species that come close to Illinois actually enter the state. One important exception is the hispid cotton rat (*Sigmodon hispidus*), and there is a good possibility that within many years it may succeed in moving northward from Reelfoot Lake, western Tennessee, into southern Illinois. Another exception is the eastern harvest mouse (*Reithrodontomys humulis*), which has been taken on the south side of the Ohio River in Kentucky. Most western species that occur near Illinois actually enter it. Two notable exceptions are the spotted skunk (*Spilogale putorius*) and western harvest mouse (*Reithrodontomys megalotis*). The Mississippi River may serve as the effective barrier to their entrance into Illinois.

*Northern species of mammals approaching, but not entering, Illinois*

Northern water shrew (*Sorex palustris*) Wis.[2]

Arctic shrew (*Sorex arcticus*) Wis.

Short-tailed weasel (*Mustela erminea*) Wis.

Least chipmunk (*Eutamias minimus*) Wis.

Red squirrel (*Tamiasciurus hudsonicus*) Wis.

Northern flying squirrel (*Glaucomys sabrinus*) Wis.

Boreal redback vole (*Clethrionomys gapperi*) (E, W) Wis.

Porcupine (*Erethizon dorsatum*) (W) Wis.

Snowshoe hare (*Lepus americanus*) (E, W) Wis.

*Eastern or northeastern species approaching, but not entering, Illinois*

Star-nosed mole (*Condylura cristata*) Wis., Ind.

Smoky shrew (*Sorex fumeus*) (N) Ind.

Woodland jumping mouse (*Napaeozapus insignis*) Wis.

*Southern or southeastern species approaching, but not entering, Illinois*

Mississippi myotis (*Myotis austroriparius*) (E) Ind.

Eastern big-eared bat (*Corynorhinus macrotis*) Tenn.

Eastern harvest mouse (*Reithrodontomys humulis*) Ky.

Hispid cotton rat (*Sigmodon hispidus*) Tenn.

*Western species approaching, but not entering, Illinois*

Spotted skunk (*Spilogale putorius*) (S) Iowa, Mo.

Western harvest mouse (*Reithrodontomys megalotis*) Mo., Iowa, Wis.

## Summary

The majority (65 percent) of the species of mammals in Illinois are wide-ranging and are to be found to the north, south, east, and west of the state. The remaining species are predominantly southern and western, and this is correlated with the invasion of southern swamplands and western prairies into Illinois. Many northern or boreal species are found just to the north of Illinois, in Wisconsin, but do not enter Illinois.

[2] The state listed after the name indicates that the species has been recorded from there.

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# SEASONAL VARIATION IN HOOP NET CATCHES AT LAKE GLENDALE

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The rise and fall in hoop net catch with change in season has been studied on a year-round basis by Roach (1942) and Hansen (1951), and on a more limited basis by Wickliff and colleagues (1944 and 1946), Barnickol & Starrett (1951), and Harrison (1951). In the present study, hoop net catches were as much as 10 or 15 times heavier at one time of year than at another, and seasonal trends in the rate of catch differed widely for different species. For these reasons it is obvious that when hoop nets (or other trap nets) are used in quantitative sampling, the date of sampling is of critical importance.

I am indebted to Agnes C. Hansen, R. Weldon Larimore, and George W. Bennett for criticizing the manuscript, and to Larimore, Leonard Durham, and W. Leslie Burger for discussions of the results.

## Collection of Hoop Net Data

Lake Glendale, the site of this netting study, is a comparatively new lake of 82 acres in southern Illinois (Pope County). The Glendale dam was completed in 1939 and the lake has been open to hook-and-line fishing since 1942. Largemouth bass[1], bluegill, green sunfish, and warmouth were the species most regularly caught by the anglers and by netting. The warmouth, however, did not appear in either angling or net catches until 1943.

The netting observations were made at Lake Glendale at about 1- to 2-month intervals, extending from early spring to late fall (March to November) during two years and for shorter periods in two other years. The operations during any one month most often consisted of three consecutive days of netting with either six or seven hoop nets. The nets were set at scattered points around the edge of the lake, mainly in the east half. The map (fig. 1), shows locations of the six nets used on the last eight trips, from August 1945 through September 1946. In general the locations of nets on earlier trips were the same as shown in fig. 1 with the exception of one or two nets per trip whose locations differed slightly from those shown. For example, Net 4 was sometimes used on the opposite side of the lake, 100 feet from its location on the map, and Net 6 was occasionally set on one side or the other of the big bay just west of its map location. In 1943, an additional net, making seven nets in all, was set half-way between nets 4 and 5 on the north side.

No special effort was made to set nets where good catches could be expected. A number of stations, in

[1] The Glendale species referred to by their common names are the bluegill (*Lepomis m. macrochirus* Rafinesque), the green sunfish (*Lepomis cyanellus* Rafinesque), the warmouth (*Chaenobryttus coronarius* (Bartram), the largemouth bass (*Micropterus salmoides* (Lacépède)), and the black bullhead (*Ameiurus m. melas* (Rafinesque)).

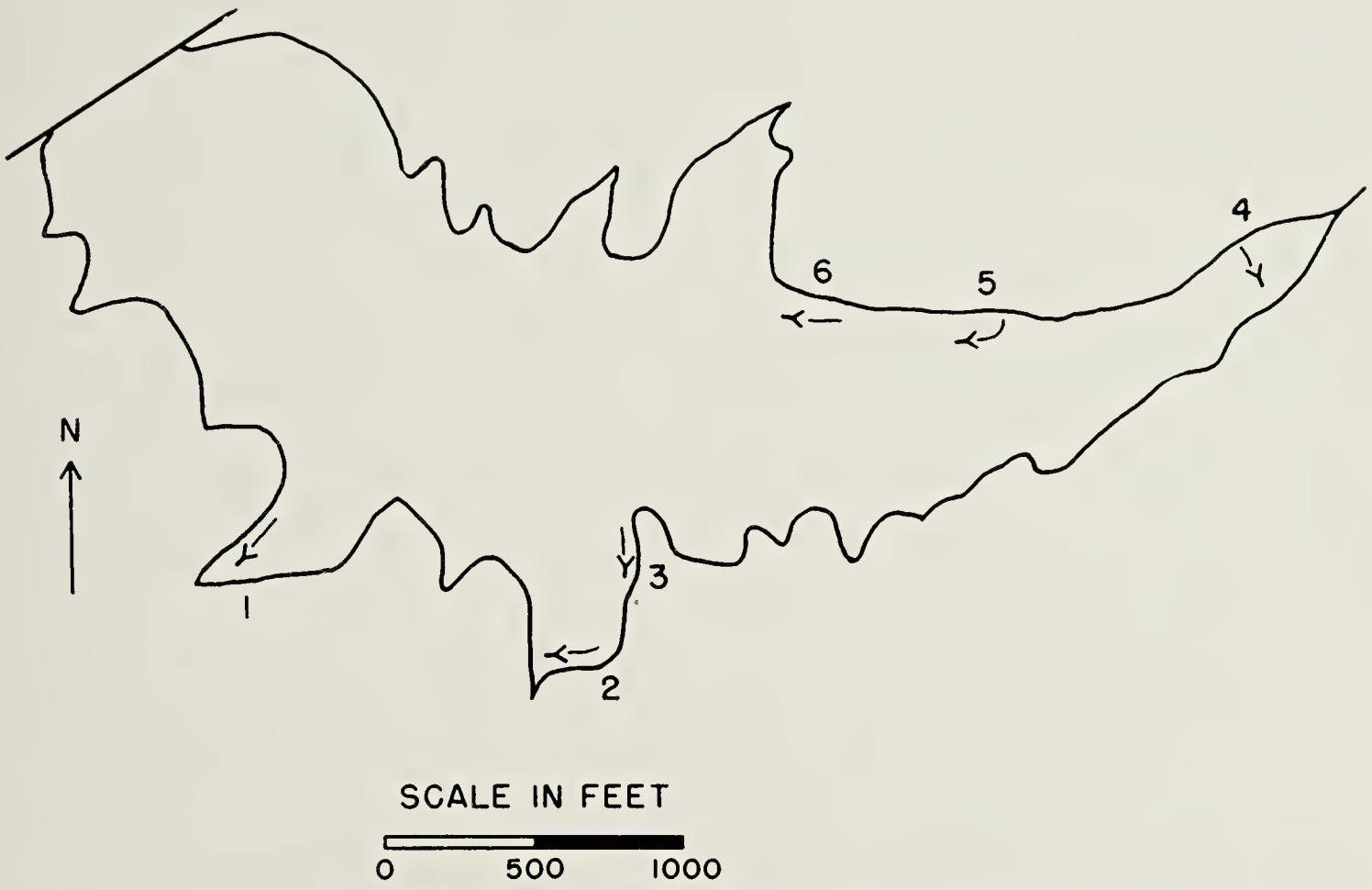


FIG. 1.—Outline map of Lake Glendale showing locations of the six netting sites used from August 1945 through September 1946 and in most of the earlier operations.

fact, quite consistently produced poor catches. In view of the variation in catch from one net to another found during the present study [the details are not given here] and previously shown by Roach (1942) and by Schumacher & Eschmeyer (1943), the practice of operating the nets at the same stations on all trips is unquestionably the best procedure for this type of study.

The hoop nets were 1-inch-square mesh, two-compartment wing nets of a design used by the Survey for many years. From the beginning of the study through March 1944, the usual collection of nets included two 2½-foot (diameter), two 4½-foot, and either two or three 3½-foot nets; from May 1944, 3½-foot nets were used exclusively. The wings on these nets were approximately 8 feet in length and the separate lead net, constructed like a seine and used in conjunction with each hoop net to guide fish toward the traps, was 60 feet in length. The hoop net proper was set in water deep enough to about cover the hoop, i.e., in water 2½ to 4½ feet deep, depending on diameter of the net. Since the bottom of this lake slopes rather steeply, most of the hoop nets were located close to the shore. For example, in fig. 1, all of the nets and their leads (except net 4) were set approximately parallel with the shoreline and about 25 feet out. Net 4, with its lead, was set at right angles to the shoreline, and the body of the net was 75 feet offshore. Net 5 was consistently set with the lead curved toward the shore. The nets were not baited.

Catches were made at various

stages of water level. Water levels varied in the spring from ½ inch to 12 inches above the crest of the spillway. In the summer when little water entered the lake, levels dropped from 12 to 18 inches below the crest of the spillway. The collection of November 30-December 1, 1944 was made when water stood 5 feet below the spillway crest. The water had been dropped intentionally to that level in late September.

The nets were emptied the day after they were first placed in the water and on each succeeding day until sampling was completed. As reported in another paper, on one trip some nets were set for 48 hours before emptying, but these catches are not included in the present analysis. The fish taken in the nets were not returned to the water. Thus, the catch on the second day was made from a smaller population than the catch of the first day, but while some conspicuous drops in catch occurred from one day to the next, this was not a consistent trend.

The daily field routine included, in addition to raising the net and examining the catch, measuring the surface temperature of the water and measuring water transparency —the latter by means of a modification of Secchi's disc—in this case the observation was made with a 4-inch diameter steel disc, painted plain white. Temperature was taken with an ordinary laboratory thermometer with bulb held approximately 2 inches below the surface.

## Results

Total catch of each species and average catch per net day are shown for each collecting date in table 1. Seasonal trends in netting rate, as observed in different years, are shown for each species taken, except the black bullhead, in figs. 2 to 6. It is, of course, a question as to how well three days of fishing represent an entire month, and this can not be settled at the present time.

Although seasonal trends in catch rate of a species tended to be similar from year to year, the actual rates tended to be high in some years and low in other years. It is possible that this was partly due to changes in population. It has appeared from changes in hook-and-line catch rates based on an intensive creel census at Lake Glendale, that from 1943 to 1946 there may have been a 50 percent drop in abundance of largemouth, a slight drop in abundance of bluegill, and 70 or 80 percent drop in abundance of green sunfish. The warmouth were definitely increasing during these years but this increase cannot be stated on a percentage basis.

The bluegill and largemouth catch rates were highest in March. Largemouth were almost uncatchable through the summer months, while bluegill catch rates dropped off more gradually and reached the lowest point in September. Catch rates of both species picked up slightly from September to November. Black bullheads were taken in very small numbers but it appears that the trend might approximate that of the largemouth and bluegill.

Seasonal trends in the catch rates of green sunfish and warmouth differed considerably from year to year, but rates tended to rise from March to September (most pronounced in the warmouth). This 7-

TABLE 1.—NUMBER OF FISH CAUGHT, AND AVERAGE CATCH PER NET AT DIFFERENT TIMES OF THE YEAR AND UNDER DIFFERENT CONDITIONS OF WATER TEMPERATURE AND TRANSPARENCY AT LAKE GLENDALE

| Dates of net raises (inclusive) | No. of hoop net catches[1] | Catch | | | | | | | | | | | | Water observations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Largemouth | | Bluegill | | Green sunf. | | Bluegill X gr. sunf. hybrid | | Warmouth | | Black bullhead | | Surface temperature degrees F. | Transparency, inches |
| | | No. | Rate | No. | Rate[2] | No. | Rate | No. | Rate | No. | Rate | No. | Rate | | |
| 1943 | | | | | | | | | | | | | | | |
| Mar. 20-22... | 20 | 147 | 7.4 | 1,329 | 66.5 | 11 | 0.6 | 3 | 0.1 | ..... | ..... | 5 | 0.3 | 48° | 4 |
| May 14 ..... | 7 | 29 | 4.1 | 427 | 61.0 | 28 | 4.0 | 2 | 0.3 | ..... | ..... | ..... | ..... | 64° | 14 |
| July 25-27... | 21 | 3 | 0.1 | 134 | 6.4 | 3 | 0.1 | 12 | 0.6 | 1 | ..... | 1 | ..... | 88° | 96 |
| 1944 | | | | | | | | | | | | | | | |
| Mar. 26-31... | 12 | 16 | 1.3 | 338 | 28.2 | 4 | 0.3 | ..... | ..... | 2 | 0.2 | 2 | 0.2 | 49° | 12 |
| May 16-18... | 18 | 2 | 0.1 | 183 | 10.2 | 18 | 1.0 | 10 | 0.6 | 9 | 0.5 | 4 | 0.2 | 80° | 23 |
| July 28-29... | 12 | ..... | ..... | 53 | 4.4 | 19 | 1.6 | 6 | 0.5 | 2 | 0.2 | ..... | ..... | 81° | 62 |
| Sept. 7-9..... | 18 | ..... | ..... | 30 | 1.7 | 38 | 2.1 | 5 | 0.3 | 10 | 0.6 | 1 | 0.1 | 77° | 62 |
| Nov. 30-Dec. 1 | 12 | 7 | 0.6 | 98 | 8.2 | 57 | 4.8 | 3 | 0.2 | 10 | 0.8 | ..... | ..... | 44° | 48 |
| 1945 | | | | | | | | | | | | | | | |
| Mar. 7-9..... | 18 | 68 | 3.8 | 1,332 | 74.0 | 17 | 0.9 | 2 | 0.1 | 11 | 0.6 | 10 | 0.6 | 46° | 7 |
| May 16-19... | 24 | 4 | 0.2 | 575 | 23.9 | 15 | 0.6 | 4 | 0.2 | 7 | 0.3 | 5 | 0.2 | 65° | 20 |
| July 25-27... | 18 | 1 | 0.1 | 273 | 15.2 | 14 | 0.8 | 10 | 0.6 | 21 | 1.2 | 2 | 0.1 | 88° | 90 |
| Aug. 15-17... | 18 | ..... | ..... | 208 | 11.5 | 6 | 0.3 | 4 | 0.2 | 10 | 0.6 | ..... | ..... | 82° | 63 |
| Sept. 6-14.... | 44 | ..... | ..... | 80 | 1.8 | 50 | 1.1 | 5 | 0.1 | 22 | 0.5 | ..... | ..... | 81° | 102 |
| Nov. 28-30... | 18 | 8 | 0.4 | 132 | 7.3 | 8 | 0.4 | 1 | 0.1 | ..... | ..... | ..... | ..... | 45° | 17 |
| 1946 | | | | | | | | | | | | | | | |
| Mar. 14-15... | 12 | 1 | 0.1 | 391 | 32.5 | ..... | ..... | ..... | ..... | 4 | 0.3 | ..... | ..... | 52° | 12 |
| June 9-11.... | 18 | ..... | ..... | 424 | 23.5 | 5 | 0.3 | 3 | 0.2 | 17 | 0.9 | ..... | ..... | 79° | 40 |
| July 20-22... | 18 | 1 | 0.1 | 212 | 11.8 | 5 | 0.3 | 5 | 0.3 | 18 | 1.0 | 1 | 0.1 | 84° | 98 |
| Aug. 21-23... | 18 | 2 | 0.1 | 33 | 1.8 | 9 | 0.5 | 3 | 0.2 | 21 | 1.2 | ..... | ..... | 80° | 60 |
| Sept. 20-22... | 18 | 2 | 0.1 | 8 | 0.4 | 18 | 1.0 | 3 | 0.2 | 26 | 1.4 | ..... | ..... | 75° | 82 |

[1] The sum of the number of nets raised on successive days.

[2] The average catch per net in 24 hours—generally referred to as the catch per net-day.

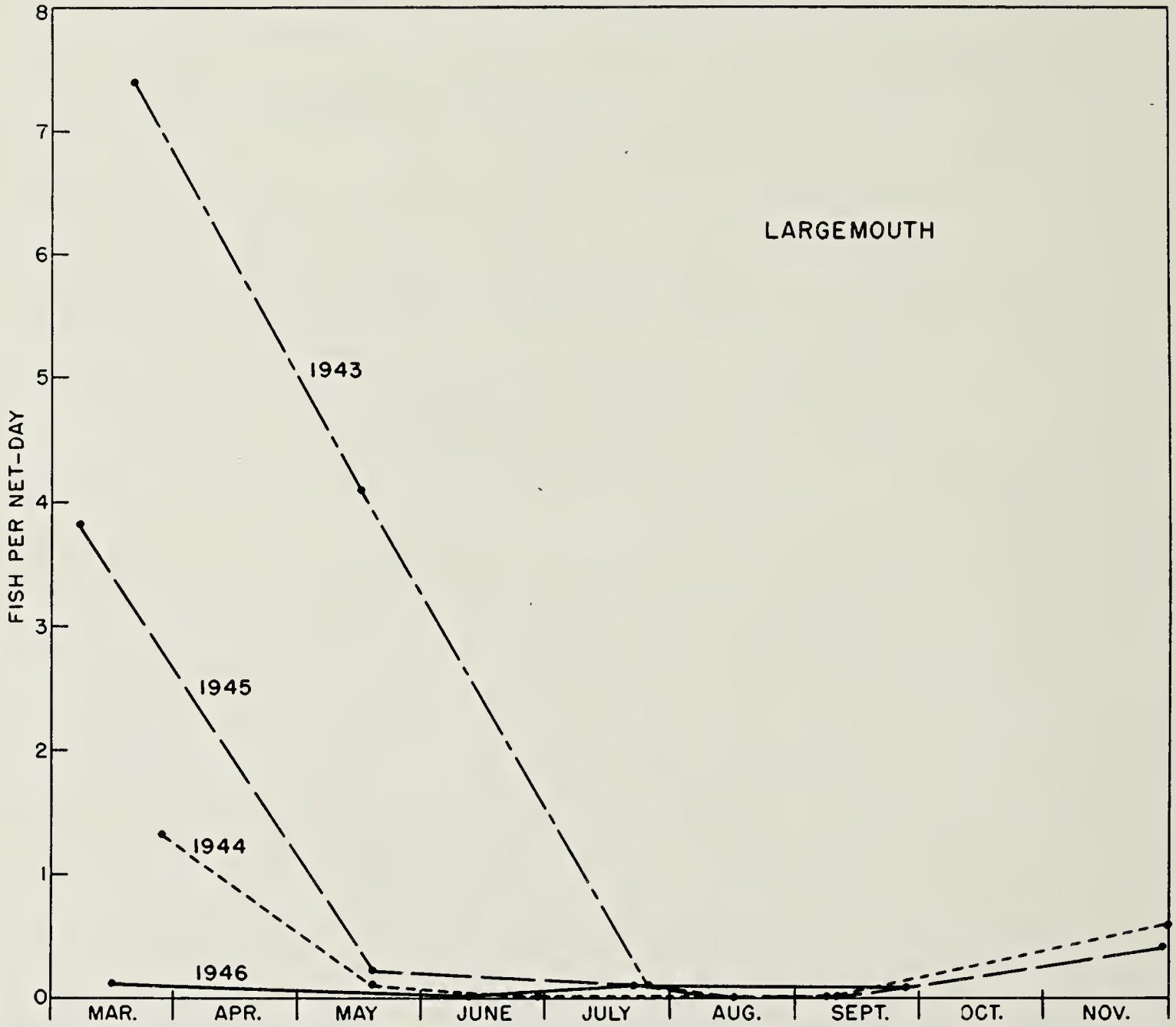


FIG. 2.—Seasonal variation in rates of catch of largemouth bass by hoop net at Lake Glendale.

month trend is opposite the trend outlined for largemouth and bluegill. The trend for the green sunfish and warmouth rates from September to November remains uncertain, since in the two November observations, rates for both species were high one year and low the other. The high rate of catch of green sunfish in May 1943 was possibly not typical; it might have been lower had netting been carried on for more than 1 day in that month. The catch rate of green sunfish showed little variation with season through 1945 and this was true of the largemouth in 1946.

The trend in the catch rate of the bluegill X green sunfish hybrid was different than that of either the bluegill or the green sunfish. From a low in March, the rate increased to a high point in July or August (May in one year) and dropped off in September and November. The increase in rate of catch from early spring to midsummer in the hybrid was marked by more steeply rising curves than those representing the green sunfish. The consistency in the seasonal trends for the catch of hybrids seems remarkable considering the small numbers actually handled.

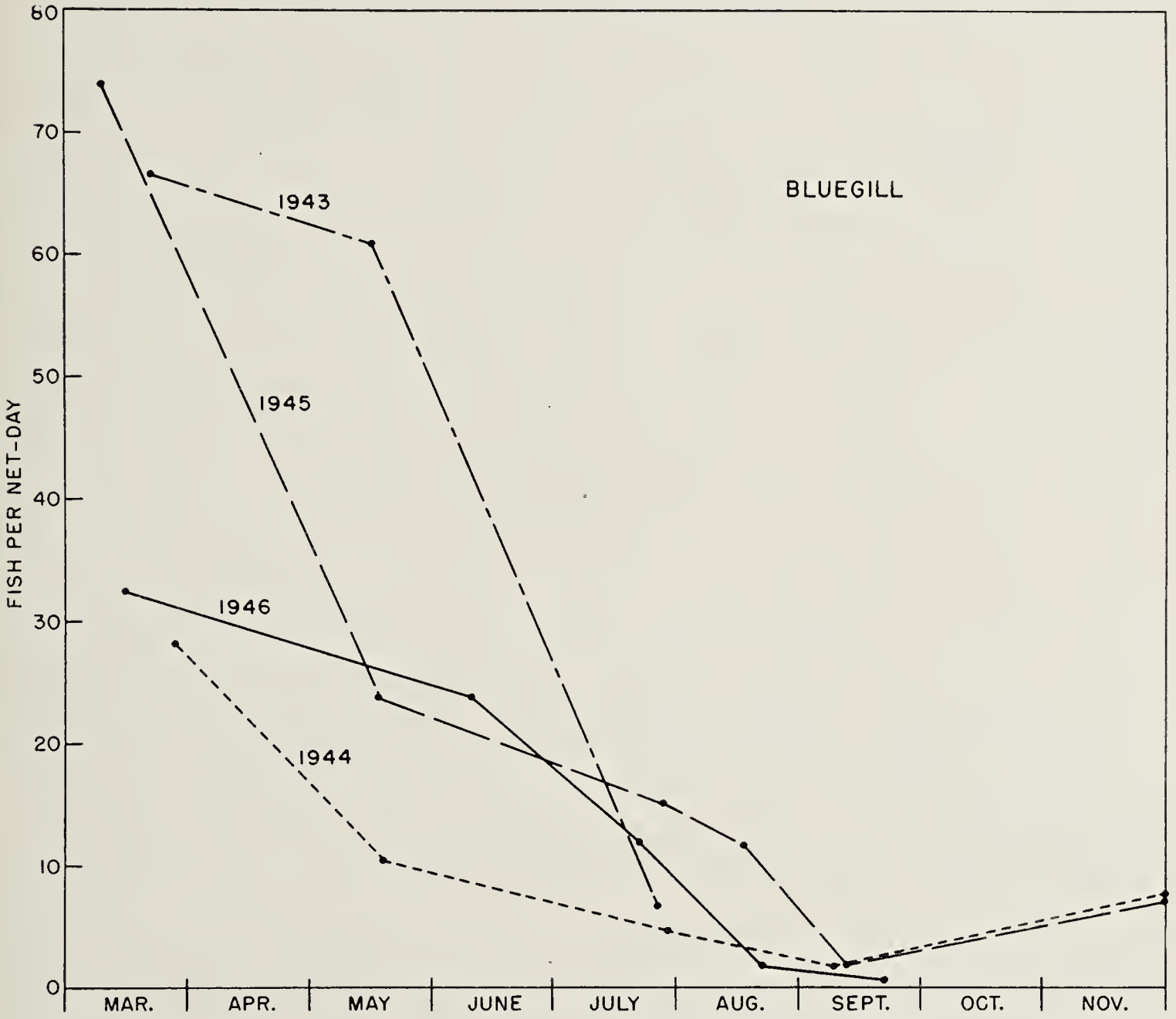


FIG. 3.—Seasonal variation in rates of catch of bluegills by hoop net at Lake Glendale.

As a result of the wide difference in these seasonal trends from one species to another, there was considerable change from one part of the year to another in the percentage composition of species in the net catches, table 2. The maximum difference here will be found between the percentage makeup of March catches and September catches—especially in bluegills, green sunfish, and warmouth. Whereas bluegills made up about 90 percent of the March catches, green sunfish and warmouth were about as abundant as bluegills in the September catches.

## SOME POSSIBLE REASONS FOR SEASONAL VARIATIONS IN CATCH

Commercial fishermen who have noted rise and fall of net catches with season generally attribute the fluctuations to changes in either temperature or turbidity, or both. It appears that a number of commercially important species netted along the Illinois River, particularly carp and buffalo, are caught best in the cooler months of the year and better in turbid water than in clear water. Some of the river fishermen claim to have seen spectacular improve-

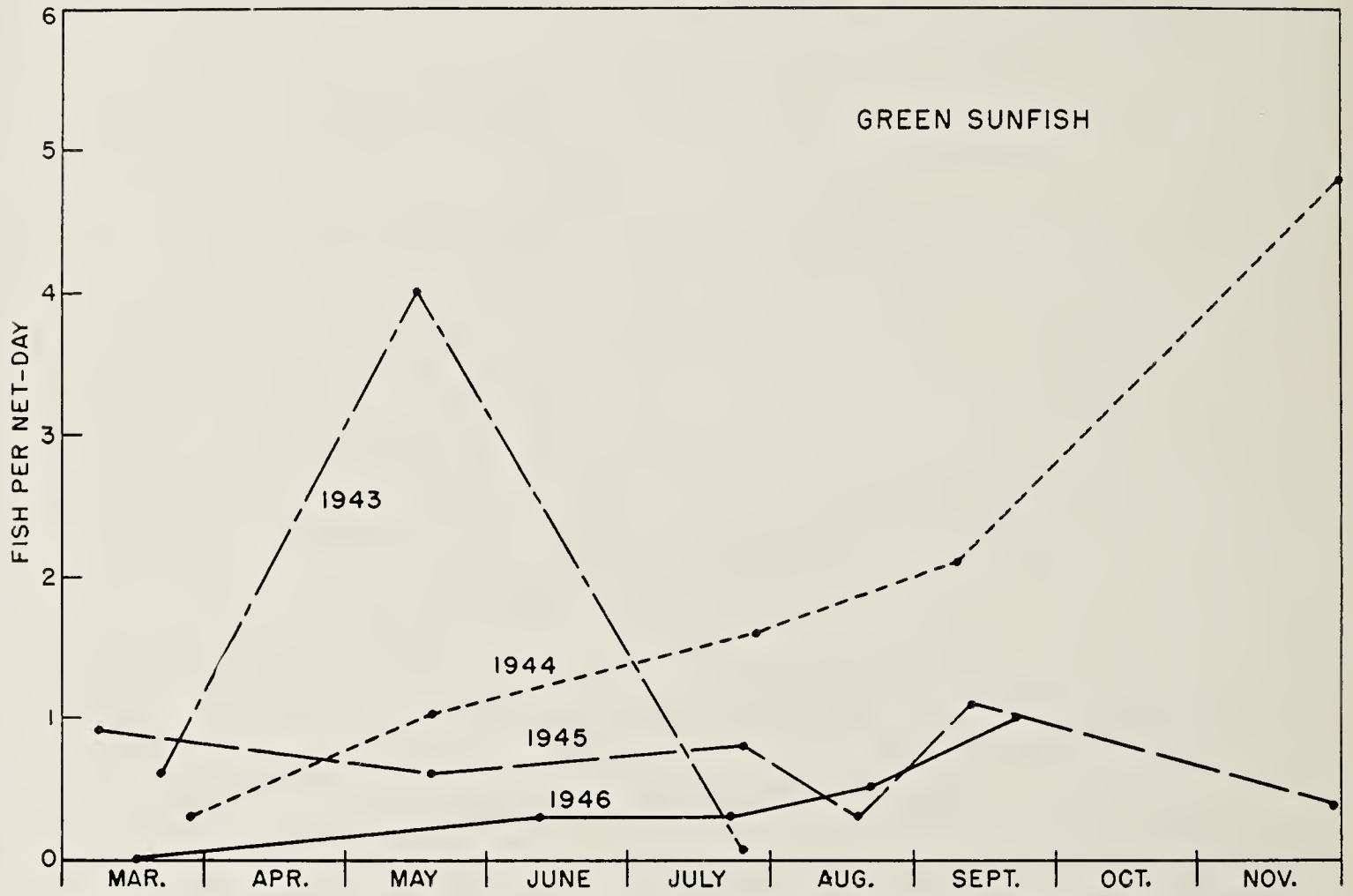


FIG. 4.—Seasonal variation in rates of catch of green sunfish by hoop net at Lake Glendale.

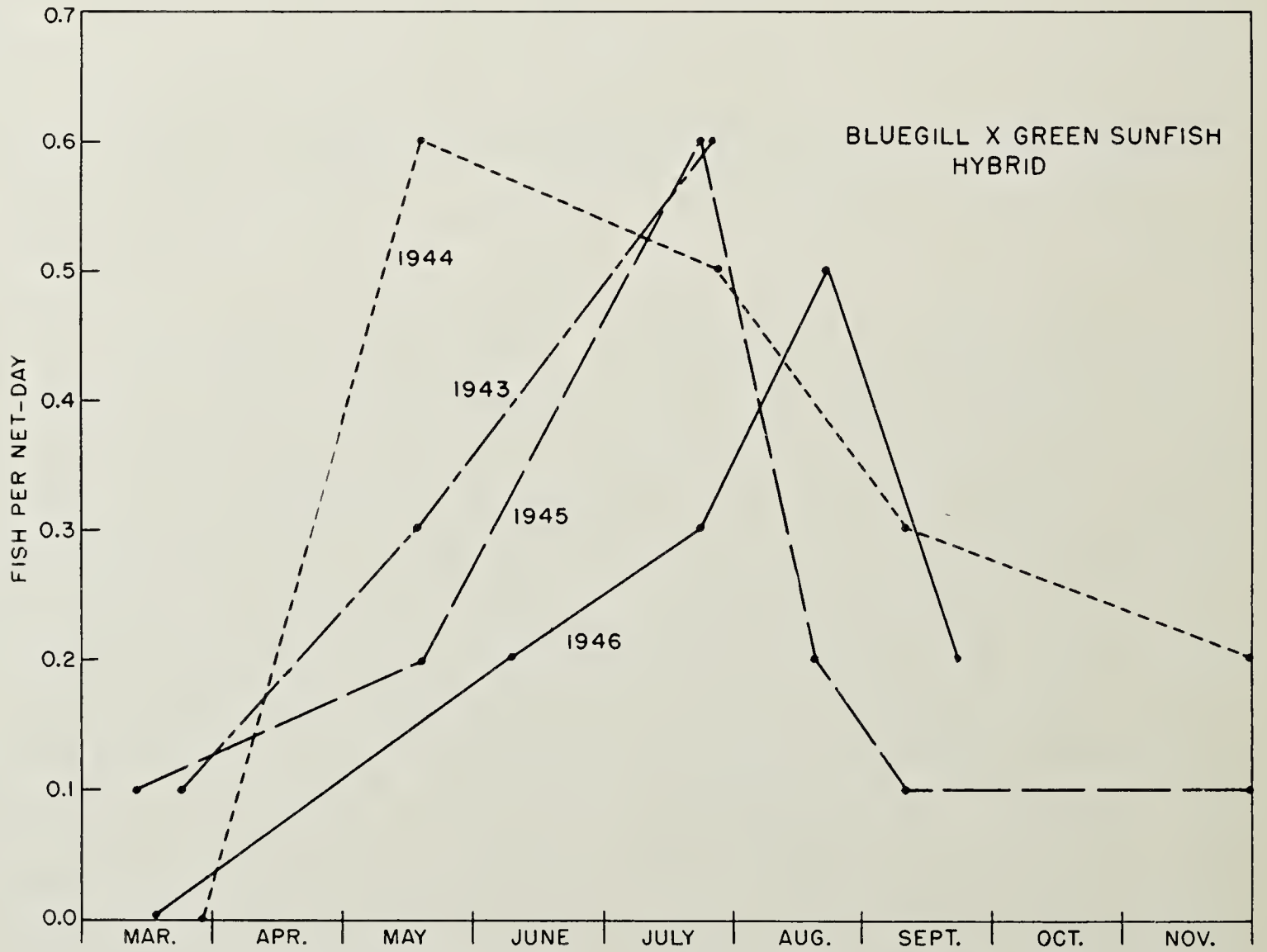


FIG. 5.—Seasonal variation in rates of catch of hybrid sunfish (bluegill crossed with green sunfish) by hoop net at Lake Glendale.

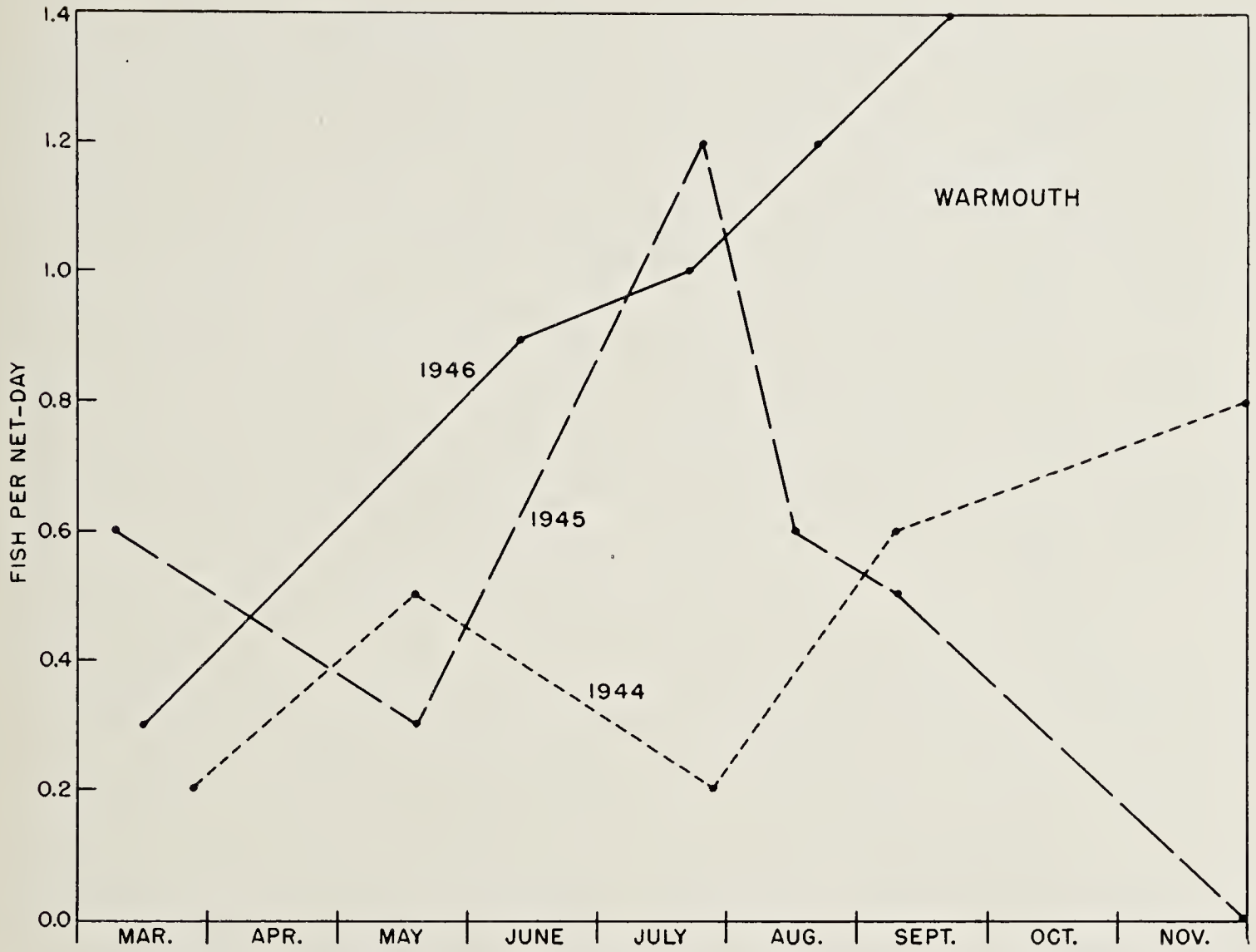


FIG. 6.—Seasonal variation in rates of catch of warmouth by hoop net at Lake Glendale.

ment in their carp and buffalo catches from one day to the next, accompanying a sharp increase in turbidity after heavy rainfall on some part of the upstream watershed. A fisherman at Havana was certain that improved catches after these storms could not be attributed to the accompanying rise in water level. He claimed that a rise in river level at Havana caused by release of clear water from Peoria Lake (by lowering the gates in the dam) was not accompanied by improved net catches. Harrison (1951) points out that any rise in level (turbidity not mentioned) results in better catches of channel cat. Although temperature and water transparency observations were made at the times of the Glendale netting operations, the importance of these as factors determining catch rate of the Glendale fishes is somewhat in doubt.

It will be noticed (see table 1) that for most species the rise and fall in netting rate does not follow the annual cycle of temperature changes. The closest thing to a correlation between the temperature cycle and the catch rate is seen in the hybrid which was caught poorly at low water temperatures in spring and fall, and best at high water temperatures in summer. Largemouth and bluegills were caught much better in March than in November at the same water temperature. And summer catches of bluegills declined steadily irrespective of temperature changes.

TABLE 2.—SPECIES COMPOSITION OF HOOP NET COLLECTIONS AT LAKE GLENDALE

| Date | Total No. | Largemouth | | Bluegill | | Green sunf. | | Bluegill X gr. sunf. hybrid | | Warmouth | | Black bullhead | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1943 | | | | | | | | | | | | | |
| Mar. 20-22 | 1,495 | 147 | 9.8 | 1,329 | 88.9 | 11 | 0.7 | 3 | 0.2 | ..... | 0.0 | 5 | 0.3 |
| May 14 | 486 | 29 | 6.0 | 427 | 87.9 | 28 | 5.8 | 2 | 0.4 | ..... | 0.0 | ..... | 0.0 |
| July 25-27 | 154 | 3 | 1.9 | 134 | 87.0 | 3 | 1.9 | 12 | 7.8 | 1 | 0.7 | 1 | 0.7 |
| 1944 | | | | | | | | | | | | | |
| Mar. 26-31 | 362 | 16 | 4.4 | 338 | 93.4 | 4 | 1.1 | ..... | 0.0 | 2 | 0.5 | 2 | 0.5 |
| May 16-18 | 229 | 2 | 0.9 | 186 | 81.2 | 18 | 7.9 | 10 | 4.4 | 9 | 3.9 | 4 | 1.7 |
| July 28-29 | 80 | ..... | 0.0 | 53 | 66.2 | 19 | 23.7 | 6 | 7.5 | 2 | 2.5 | ..... | 0.0 |
| Sept. 7-9 | 84 | ..... | 0.0 | 30 | 35.7 | 38 | 45.2 | 5 | 5.9 | 10 | 11.9 | 1 | 1.2 |
| Nov. 30-Dec. 1 | 175 | 7 | 4.0 | 98 | 56.0 | 57 | 32.6 | 3 | 1.7 | 10 | 5.7 | ..... | 0.0 |
| 1945 | | | | | | | | | | | | | |
| Mar. 7-9 | 1,440 | 68 | 4.7 | 1,332 | 92.5 | 17 | 1.2 | 2 | 0.1 | 11 | 0.8 | 10 | 0.7 |
| May 16-19 | 610 | 4 | 0.6 | 575 | 94.3 | 15 | 2.5 | 4 | 0.6 | 7 | 1.1 | 5 | 0.8 |
| July 25-27 | 321 | 1 | 0.3 | 273 | 85.0 | 14 | 4.4 | 10 | 3.1 | 21 | 6.5 | 2 | 0.6 |
| Aug. 15-17 | 228 | ..... | 0.0 | 208 | 91.2 | 6 | 2.6 | 4 | 1.7 | 10 | 4.4 | ..... | 0.0 |
| Sept. 6-14 | 157 | ..... | 0.0 | 80 | 50.9 | 50 | 31.8 | 5 | 3.2 | 22 | 14.0 | ..... | 0.0 |
| Nov. 28-30 | 149 | 8 | 5.4 | 132 | 88.5 | 8 | 5.4 | 1 | 0.7 | ..... | 0.0 | ..... | 0.0 |
| 1946 | | | | | | | | | | | | | |
| Mar. 14-15 | 396 | 1 | 0.2 | 391 | 98.7 | ..... | 0.0 | ..... | 0.0 | 4 | 1.0 | ..... | 0.0 |
| June 9-11 | 449 | ..... | 0.0 | 424 | 94.4 | 5 | 1.1 | 3 | 0.7 | 17 | 3.7 | ..... | 0.0 |
| July 20-22 | 242 | 1 | 0.4 | 212 | 87.6 | 5 | 2.1 | 5 | 2.1 | 18 | 7.4 | 1 | 0.4 |
| Aug. 21-23 | 68 | 2 | 2.9 | 33 | 48.5 | 9 | 13.2 | 3 | 4.4 | 21 | 30.9 | ..... | 0.0 |
| Sept. 20-22 | 57 | 2 | 3.5 | 8 | 14.0 | 18 | 31.6 | 3 | 5.3 | 26 | 45.6 | ..... | 0.0 |

That the several species of fish in Lake Glendale were caught differently under various combinations of temperature and transparency can be seen in table 1. In the spring when the water was cool and cloudy, bluegills and largemouth were caught in relatively large numbers while green sunfish, warmouth, and hybrids were caught in small numbers; on the other hand, in middle and late summer when the water was warm and clear, bluegills and largemouth were caught with difficulty while the others were caught with more success.

The commercial fishermen claim that warm summer temperatures cause fish to descend into deeper, cooler water than that occupied through the spring months; they also claim that fish are less active in warm water than in cool water, and therefore are less likely to be caught, and that certain species are more wary of nets in clear water (where nets are plainly visible) than of the same nets set in muddy water. These explanations cover summer declines in netting rates—not summer improvement.

Cady, Dendy, and Haslbauer (1945) have presented evidence of seasonal depth changes in largemouth bass, based on gill net operations at Norris Lake. In contrast to the net fisherman's apparent notion that there is a general movement of the entire population to deeper water during hot weather, the Norris Lake study instead shows that the largemouth population covered a wider range of depths in summer than in spring. Some bass were found in shallow water from March to October, but occurrences of bass in water more than 20 feet in depth were rare except in summer, and possibly fall. Few of the Norris Lake bass descended deeply enough during hot weather to get into water cooler than that at the surface. In other words, most of them remained in the warm water above the thermocline, even though the cooler water within the thermocline was well supplied with oxygen. Obviously, the Glendale catch records do not suggest that green sunfish, warmouth or hybrids move to deeper water in summer.

Other reasons for changing depth with season might be preference for certain light conditions, a preference for certain foods, or preference for a certain spawning depth.

It is not yet possible to verify the fisherman's claim that activity declines with rise in water temperature. Fry (1947) concluded that cold-blooded animals at least are capable of greater activity at high temperatures than at low temperatures, but this does not constitute a demonstration that they actually are more active.

Theoretically, there are other ways in which high turbidity may work to improve catch, in addition to the idea that turbidity helps to overcome fish wariness. One is that muddiness may stimulate fish to greater activity, possibly in an effort to find clean water—presuming that some species may have that preference. And high turbidity may interfere with fishes' efforts to escape from nets. Moderate turbidity, however, may not constitute a serious handicap to escapement (Hansen, 1944).

There remains one more possibly important reason for seasonal fluctu-

ations in netting rates. These fluctuations may be caused by real increases and decreases in the number of fish of nettable size. Scale studies by Hansen (1951) showed that the summer decline in catches of white crappies in hoop nets in Lake Decatur was mainly the result of heavy spring or summer mortality among the older fish. Again at Lake Decatur, a large increase in fall netting rate was found in certain years to be caused by the capture of large numbers of fish in their second year of life which previously had been too small to hold in the nets or for some other reason had not been caught.

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# TIME OF FEEDING OF THE BLACK CRAPPIE AND THE WHITE CRAPPIE

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Hansen (1951) in reporting the biology of the white crappie cited some unpublished data collected by David H. Thompson pertaining to differences in day and night hoop-netting catches of black crappie (*Pomoxis nigromaculatus*) and white crappie (*Pomoxis annularis*). He stated that "morning raises yielded more blacks than whites, evening raises more whites than blacks."

During the winter of 1952 the authors became interested in seeing if this experiment could be repeated in the laboratory and, if so, whether the difference in the catch was because of a difference in the feeding times of the two species.

The crappies used in this experiment were obtained from Lake Chautauqua near Havana, Illinois, and had been kept in an aquarium approximately two months. Five white crappies were placed in one of two 300 gallon aquaria and five blacks in the other.

There was a continuous flow of dechlorinated water into each aquarium and the water temperature was equalized in the two aquaria by increasing or decreasing the rate of flow. The temperature fluctuated from 16° to 22° C. during the experiment but there was never more than 1° difference between the aquaria at any one time. They were located in a greenhouse where light conditions were comparable to those out-of-doors.

By January 7, 1953, preliminary trials had indicated the desirability of the following procedures. Minnows were chosen as the only food for the crappie. We intended to use only bluntnose minnows (*Hyborhynchus notatus*) but on a few occasions when these were not available a few silverjaw minnows (*Ericymba buccata*) and still fewer creek chubs (*Semotilus atromaculatus*) were used. When the minnow species was changed in one aquarium, it was simultaneously changed in the other. The feeding times were so arranged that there were always some minnows present. The number was restored to ten at each of the times minnow counts were made at 6:00 A.M., 8:00 A.M., 4:00 P.M., and 6:00 P.M. Because so many minnows were eaten during the morning and evening periods, minnow counts were also made at 7:00 A.M. and 5:00 P.M. The first four checking points divide the winter day into four periods, one completely dark, one completely light, one growing dark (dusk), and one growing light (dawn).

After eight days of observations, each species was removed to the aquarium previously occupied by the other. This was done in order to rule out any possible unforeseen environmental differences which could have influenced the feeding time. The experiment was then continued until February 10, 1953.

TABLE 1.—THE NUMBER OF MINNOWS EATEN BY BLACK CRAPPIES AND THE TOTAL NUMBER OF HOURS FOR EACH PERIOD

| | Dawn 6-7 | Dawn 7-8 | Day 8-4 | Dusk 4-5 | Dusk 5-6 | Night 6-6 |
|---|---|---|---|---|---|---|
| Minnows eaten: | | | | | | |
| January 7–January 14 | 13 | 7 | 4 | 30 | 46 | 98 |
| January 15–January 25 | 9 | 6 | 3 | 10 | 14 | 37 |
| January 26–February 10 | 10 | 1 | 2 | 2 | 22 | 17 |
| Total minnows eaten | 32 | 14 | 9 | 42 | 82 | 152 |
| Total Hours | 19 | 19 | 240 | 32 | 32 | 228 |

Table 1 shows the number of minnows consumed by the black crappies during each period and the total number of hours during which these minnows were eaten.

Table 2 for the white crappies shows that they ate a total of 580 minnows as compared to the 331 eaten by the blacks. Because the white crappies ate more they were fed larger minnows in order to decrease the possibility of all ten minnows being consumed during any one period. Therefore, the difference between the two species in the total volume of food eaten is even greater than suggested by these figures.

Table 3 shows the percentage of food consumed in each period. The chief difference between the species is found in the day period. Though the white crappie fed less during the day than at any other time, the amount eaten then (19 percent) greatly exceeded that of the black crappie (2.7 percent). Because the dusk and dawn feedings of the two species were so nearly the same, the night feeding of the black crappie would necessarily be greater than that for the whites.

In order to treat the data statistically we used the average percentage of food consumed per hour for

TABLE 2.—THE NUMBER OF MINNOWS EATEN BY WHITE CRAPPIES AND THE TOTAL NUMBER OF HOURS FOR EACH PERIOD

| | Dawn 6-7 | Dawn 7-8 | Day 8-4 | Dusk 4-5 | Dusk 5-6 | Night 6-6 |
|---|---|---|---|---|---|---|
| Minnows eaten: | | | | | | |
| January 7–January 14 | 27 | 19 | 39 | 34 | 37 | 113 |
| January 15–January 25 | 17 | 10 | 44 | 20 | 18 | 57 |
| January 26–February 10 | 12 | 4 | 27 | 12 | 47 | 43 |
| Total minnows eaten | 56 | 33 | 110 | 66 | 102 | 213 |
| Total Hours | 19 | 19 | 240 | 32 | 32 | 228 |

TABLE 3.—THE PERCENTAGE OF TOTAL FOOD CONSUMED DURING EACH OF THE FOUR PERIODS

| | Dawn 6-8 | Day 8-4 | Dusk 4-6 | Night 6-6 |
|---|---|---|---|---|
| Black Crappies | 13.9 | 2.7 | 37.5 | 45.9 |
| White Crappies | 15.3 | 19.0 | 29.0 | 36.7 |

each species for each period. It was necessary to use percentage of food eaten rather than number of minnows in the comparison because of the difference in size of minnows.

In order to show the rate of feeding for the different periods, the average percentage of food eaten per hour is presented in table 4. It is interesting to note that the period of greatest feeding intensity for both species was at dusk, though the percentage per hour was somewhat greater for black crappies than for the whites. The rate of feeding at dawn was much less than at dusk for both species. The rate at night dropped to about half of that at dawn for both species, and the rate during the day for the whites is about eight times that of the blacks.

Statistical "t" value comparisons were made not only to determine the intensity of feeding activity for each of the two species of crappie but also to compare the feeding rates of the blacks with that of the whites at different periods of the day.

For black crappie the differences between day and dusk, day and night, and dusk and night were significant to the .01 level. The difference between day and dawn (.05) is also significant though not to as high a degree.

For the white crappie the differences between the day and dusk, and day and dawn were significant to the .01 level but none of the other period differences were significant because they did not reach the .05 level.

When the activity of black crappie was compared with that of the whites for corresponding periods the difference between the two species for the day period was significant to the .01 level. All other differences were not statistically significant to the .05 level; however, the results tend to indicate that black crappies

TABLE 4.—THE PERCENTAGE OF TOTAL FOOD CONSUMED PER HOUR DURING EACH OF THE FOUR PERIODS

| | Dawn 6-8 | Day 8-4 | Dusk 4-6 | Night 6-6 |
|---|---|---|---|---|
| Black Crappies | 6.9 | 0.3 | 18.7 | 3.8 |
| White Crappies | 7.6 | 2.4 | 14.5 | 3.1 |

are more active than white crappies during the night and dusk periods while whites are more active than blacks during the dawn period.

It is interesting to compare the numbers of black and white crappies reported hoop-netted by Thompson with the percentage of day and night food consumption in the present experiment. Thompson reported 3,063 white crappie taken during the night set and 1,376 during the day. There were 6,886 black crappie taken during the night and only 879 during the day. In other words, about 89 percent of the blacks were caught at night as compared to the 70 percent of whites caught at night. Because Thompson's night period included what we called dusk, night, and dawn, we totaled these three periods in our experiment for comparison. We found 97 percent of the activity for the black crappie to be during these periods in comparison to his 89 percent. Similarly, we found 81 percent of the activity of the whites to be in these periods as compared to his 70 percent. These results agree in indicating that white crappies are more active during the day than blacks. They should not be interpreted to mean that the black crappie is nocturnal and the white diurnal. Such a statement is made by Allee et al. (1949), who used this to account for the speciation of the two crappies. The small difference in their activity could hardly account for their reproductive isolation.

Clausen (1936) in his study of the hourly oxygen consumption of several species of fishes included the white crappie. It is interesting to note that the periods of greatest oxygen consumption corresponded to the dawn and dusk periods. As Clausen's fish were without food it would appear that crappies have a natural tendency to be active at these periods.

## Summary

1. Under laboratory conditions both black and white crappies had a daily rhythm in feeding activity.

2. The feeding activity of both species was more intense at dawn and dusk.

3. The most striking difference between black and white crappie feeding time was during the day when the whites fed about 8 times as much as the blacks, though this was also the period of lowest feeding intensity for the white crappie.

4. The differences in feeding activity of white and black crappies appeared to be very similar to the differences in catches of day and night hoop-netting.

5. Periods of feeding activity for both species corresponded to the period previously found to have the greatest oxygen consumption in the white crappie.

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# ANALYSIS OF THE GIZZARD SHAD POPULATION OF CRAB ORCHARD LAKE, ILLINOIS

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Crab Orchard Lake has a surface area of 6,500 acres with an average maximum depth of 15 to 20 feet. Its shore line is extremely irregular. The principal fishes in order of their probable abundance are: gizzard shad, *Dorosoma cepedianum* (Le Sueur); carp, *Cyprinus carpio* (Linnaeus); white crappie, *Pomoxis annularis* (Rafinesque); largemouth black bass, *Micropterus salmoides* (Lacepede); and yellow bass, *Morone interrupta* (Gill). Details on this fish population have been published by Whitacre (1952).

The present study* deals with the age-composition and rate-of-growth of a sample of 888 gizzard shad taken from Crab Orchard by use of an electric shocker. The shocker used consisted of a 230 volt A. C., 5000 watt, 180 cycle generator carried in a boat and connected to electrodes mounted on a boom extending forward from the bow of the boat. The total sample was taken at one time and the sample is thought to be representative of the population. Comments based on other observations of this population are also made.

The gizzard shad is generally accepted as important both in abundance and as a forage species (Lagler and Ricker, 1943; Swingle, 1949; and Stroud, 1949). It is found in all the larger streams and many of the lakes, and is particularly abundant in Crab Orchard Lake. Of the several abundant species of fishes in the lake, the largemouth feeds most heavily on the shad. As we come to understand more about vulnerability and palatability of forage species, there is little doubt but that the gizzard shad will be recognized as one of the most important of forage fishes for the largemouth bass and yellow pike perch.

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## Acknowledgments

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## Results

The length-frequency distribution of this fish as shown in figure 1 brings out several points of interest. There is a mode at approximately 70 millimeters of standard length, one at about 115 millimeters, and a third at 145. Assuming that all size

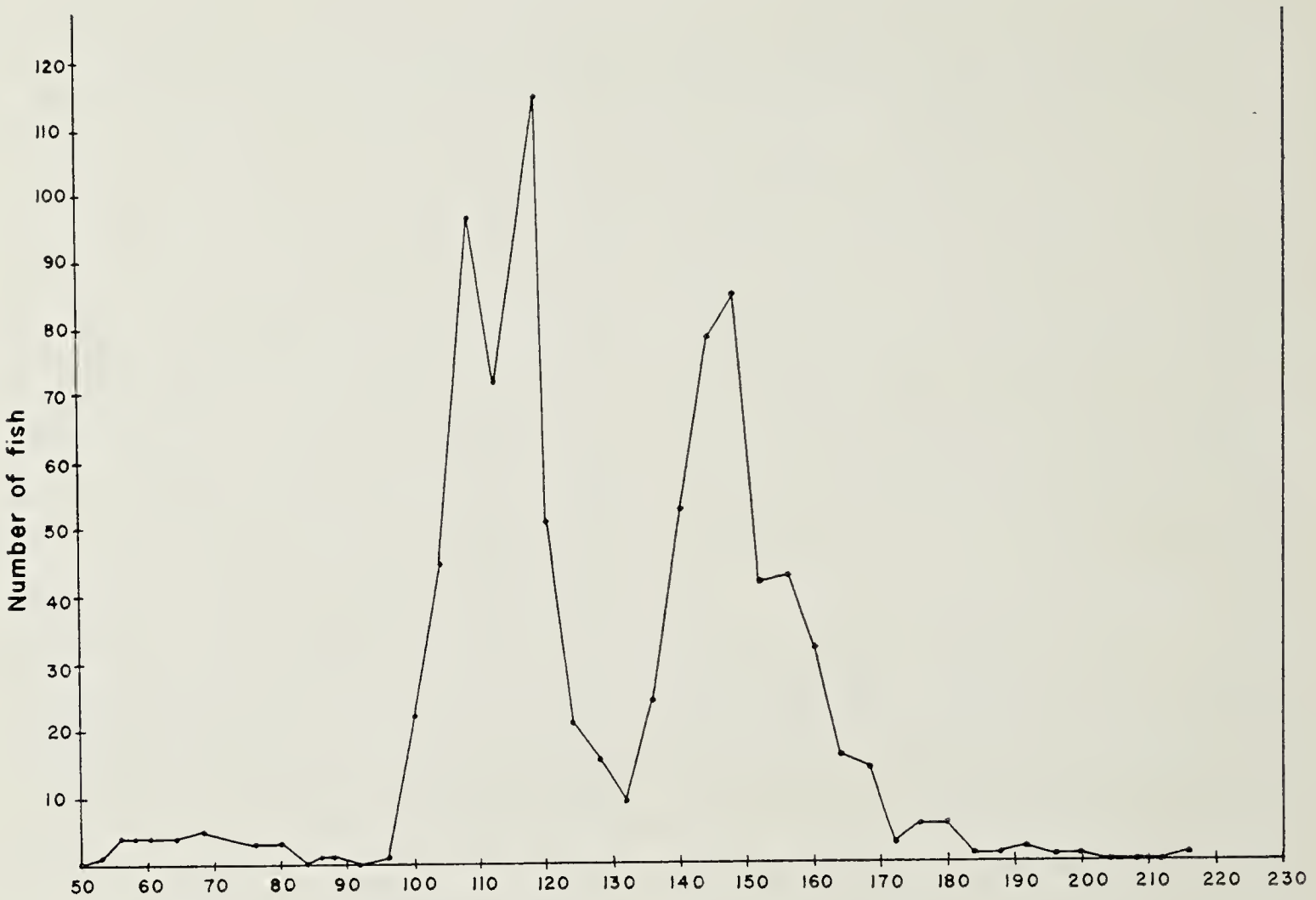


FIG. 1.—Length-frequency distribution of 888 gizzard shads taken from Crab Orchard Lake.

fishes were equally vulnerable to the collecting device, the first mode would be age group 0. The second mode is, of course, age group I and the third is age group II. These modes, in general, corroborate the ages determined by the scale method (table 1).

The sample was composed primarily of fish small enough to be utilized by adult bass. For example, it would not be out of order to assume that a two-pound bass could swallow a six-inch shad. The great majority of the shad were below six inches in length.

Table 1, which gives the ages and rate of growth based upon the scale method, shows only a few specimens older than three years. The maximum age attained was five years. The average length was 4.0, 5.4, and 6.6 inches at the end of the first, second and third years of life respectively.

The coefficient of condition, K, based on 888 specimens of the shad, length range 51 to 216 millimeters, was 1.82. Calculations were made according to length groups and no variation of K with length was detectable.

## SUMMARY

Crab Orchard Lake is a 6,500 acre artificial impoundment in southern Illinois. The fishes present in the lake in order of their abundance are: gizzard shad, carp, white crappie, largemouth black bass, and yellow bass.

TABLE 1.—AGE COMPOSITION AND SIZE OF 888 GIZZARD SHAD TAKEN FROM CRAB ORCHARD LAKE, AUGUST, 1952

| Age group | Number examined | Standard length in mm. at capture | Aver. calculated length at each annulus | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| 0 | 17 | 70 | ..... | ..... | ..... | ..... | ..... |
| I | 377 | 114 | 78 | ..... | ..... | ..... | ..... |
| II | 340 | 143 | 80 | 107 | ..... | ..... | ..... |
| III | 80 | 154 | 88 | 115 | 134 | ..... | ..... |
| IV | 5 | 171 | 84 | 94 | 125 | 139 | ..... |
| V | 1 | 150 | 74 | 86 | 106 | 117 | 129 |
| Mean standard lengths, millimeters | ..... | ..... | 80 | 108 | 133 | 135 | 129 |
| Equivalent total length, inches[1] | ..... | ..... | 4.0 | 5.4 | 6.6 | 6.7 | 6.4 |
| Annual increment, standard length, millimeters | ..... | ..... | 80 | 26 | 19 | 13 | 12 |
| Corresponding weight in grams[2] | ..... | ..... | 10 | 23 | 40 | 41 | 36 |

[1] Total length equals 1.26 standard lengths (Whitacre, 1952).
[2] Log weight = —4.13655 + 2.71106 × Log length. This formula is based on 888 specimens in the length range 51 to 216 millimeters of standard length.

In October, 1952, by counting sample strips of shore line, it was estimated that 10,250,000 shad were dead along the shore line. All size fishes were affected, but an electrical sampling in October showed three-inch shad to be very abundant, but larger sizes scarce. Since similar die-offs have occurred in this lake, it will be of interest to take additional samples in subsequent years and analyze their length-frequency distribution. Such die-offs may control the age and size composition of the population.

A sample of 888 gizzard shad was taken by electrical shocking in August, 1952. A length-frequency distribution was made of this sample of fish. Ages were determined by the scale method. It was found that the majority of fish making up the gizzard shad population were less than four years of age and small enough to be eaten by adult bass.

The shad were 4.0, 5.4, and 6.6 inches long at the end of their first, second, and third years of life respectively.

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# PRELIMINARY REPORT ON PHEASANT STOCKING IN SOUTHERN ILLINOIS[1]

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Pheasants, *Phasianus* spp., were first introduced into the United States late in the 18th Century. The first populations were not well established until late in the 19th Century when the first shooting was permitted in Oregon (McAtee, 1945). Virtually every state has attempted to encourage the development of harvestable populations, but only 18 states have thus far been successful.

The 37° parallel appears to be the approximate boundary of its southward distribution (Christisen, 1951). Many postulations have been offered as to the factors responsible for this limitation, but few of these have been carefully examined. Yeatter (1950), studying the effects of preincubation temperatures, suggested that probably air temperatures during egg laying were an important influence. He further suggested that two or more western populations, thriving considerably south of the distribution in the remainder of the United States, might be largely of a more southern Asiatic origin, being more tolerant of higher temperatures.

The objective of the present study was to make detailed observations of the survival and reproduction of released game-farm pheasants in southern Illinois. It was hoped that further insight into factors limiting their present distribution might be obtained.

An opportunity to begin the investigation came in 1950 when the State Department of Conservation liberated pheasants in early April on two localities of the Crab Orchard National Wildlife Refuge. Six weeks later, observations were begun on about 100 acres where 300 birds had been stocked in ratios of five hens to one cock. The birds had dispersed widely and offered little opportunity for detailed observations.

To eliminate the dispersal factor and to facilitate careful observation of released birds, a study was undertaken in 1951 and continued in 1952 on an island in Crab Orchard Lake, located in the Crab Orchard National Wildlife Refuge. Birds were supplied by the Illinois Department of Conservation from the Mt. Vernon Game Farm. Some 22 and 27 birds were released in April, 1951, and February, 1952, respectively. Sex ratios were approximately one male to five females. Prior to liberation all birds were pinioned by removing the manus according to the Van den Akker (1947) method.

The release island, consisting of seven acres, contained an abandoned peach (*Prunus persica*) orchard of which one-fourth was undergrown to a relatively heavy stand of broom-sedge, *Andropogon virginicus*. The remainder of the orchard contained isolated clumps of broom-sedge, scattered stands of Korean lespedeza,

[1] Special research grant, Southern Illinois University, Carbondale.

*Lespedeza stipulacea,* blue grass, *Poa pratensis,* dewberries, *Rubus* sp., coralberry, *Symphoricarpos orbiculatus,* and several miscellaneous herbaceous plants in lesser abundances. The west and south edges of the island were covered with a dense stand of shingle oak, *Quercus imbricaria,* honey locust, *Gleditsia triacanthos,* and red elm, *Ulmus rubra,* thirty to fifty feet in height. A small pond surrounded by black willow, *Salix nigra,* was located in the center of the island. The mainland was approximately 100 yards from the island at the closest point. No predaceous mammals were resident on the island during the study and no sign occurred to indicate visits. During the summer fishermen and bathers occasionally used a small sandy beach.

To insure a constant food supply, shelled corn was scattered under fruit trees that were well distributed over the island. The birds ate the corn, native seeds, and succulent vegetation, as was shown by crop contents of dead birds.

## Behavior

Behavior of the birds during the first few days following liberation paralleled that observed at the game farm. Little evidence was noted of fear reactions or of attempts to remain in cover. By the tenth to fifteenth day, however, they appeared to have become more wary, staying closer to cover, but failed to exhibit a great degree of wildness at any time.

In 1951, three males were noted to have established territories and "crowing areas" on three opposite corners of the island. Each used a site which included a canopy of trees and was relatively free of ground vegetation. Individual cocks could be identified by tracks in the loose soil, having been individually toe clipped for this purpose. Crowing was heard largely in early morning and on three occasions, hens were noted moving toward, or were with the cocks at this time. These observations reflected the findings of Baskett (1947) for northern Iowa.

## Mortality

During the initial observations on the mass releases in 1950, 43 carcasses and ten living birds were found. The bulk of the dead birds were within 80 rods of the point of liberation. The condition of the remains indicated that mortality had occurred shortly following release. It was not possible to evaluate factors responsible for the losses.

In 1951, two hens were lost from pinioning immediately following the release on April 27. No further evidence of loss was noted until June 15 when three dead hens were found showing no apparent signs of predation. By July 15, a total of nine dead birds had been found; however, field evidence indicated that the loss was probably 12 to 14 birds. The last living birds were observed on September 10, and, by October 1, no further sign of them was in evidence.

One cock and one hen were lost from pinioning in 1952 immediately following their release on February 22. By March 10th, 11 had been lost and by April 1 the loss had reached 18 birds. Following June 10, no further sign of pheasant was found.

Factors responsible for the 1951 losses were largely undetermined, but predators (avian) were not believed important. Most birds showed no signs of injury, were in good flesh, and had food in the crops. The manager of the Mt. Vernon Game Farm reported mortality in the laying flock from an undetermined cause. Possibly the same factor may have produced losses among the experimental birds. Crows, *Corvus brachyrhynchos,* were secondary predators.

Observations in 1952 indicated that the predatory marsh hawk, *Circus cyaneus hudsonius,* was responsible for a high rate of mortality. On three occasions, these predators were observed attacking pheasants. They dove at the birds, slashed them across the back or head with their talons, but made no attempt to feed on them. Such injured or dead birds were found under vegetation where it appeared that they had attempted to hide after being injured. These hawks were daily in evidence over and around the island in numbers of one to four. Eighteen losses were attributed to their activity. The fact that the 1952 releases were made during hawk migration may have attracted and held the marsh hawks to this limited area. The later liberation in 1951 possibly avoided this concentration.

## Nesting

Eighteen pheasant nests were found on the 100-acre area in 1950, but only one of these indicated a successful hatch. Six of the remainder contained undisturbed eggs and the others showed evidences of predation. The deserted clutches had an average of 7.9 eggs. Examination of these showed an advance stage of desiccation so that field determination could not be made regarding embryo development. It was not possible to determine the nature of the predation, or whether it was a primary or secondary factor. A brood of six was observed in this area the first week in July. Observations in October indicated that possibly eight to twelve birds were in the area.

In 1951, because of the delay in starting the project, egg laying had already started when the birds were released. As a result, first evidences of laying were "dropped eggs." The earliest nest was believed established three or four days following the release. The last nest found was started around July 16.

Most nests were well constructed, having a lined bowl. Few nests had a canopy but were well concealed from all sides. Eighty per cent of the nests were in broom-sedge, situated between clumps of the vegetation, where natural depressions and nest lining materials were found. Heavy stands of this grass were used only at the edges or where thinnings were in evidence. The remaining nests were in miscellaneous weedy vegetation. Ninety-two per cent (18) of the nests of pheasants released on the unrestricted area of the Refuge in 1950 were located in thin to moderately heavy stands of broom-sedge.

Eleven completed clutches of the island birds ranged in size from six to 18 eggs, showing an average of 9.7 eggs. The first four clutches, however, had an average of 15.5 eggs, indicating that these nests were possibly the efforts of more than

one bird although initial clutches may occasionally be that size.

Of the nests in 1951, 87.5 percent (14) were unsuccessful. Ten of the 14 deserted nests were believed to have resulted from crow and turtle predation. Turtle droppings examined during May 20 to June 25 revealed a 63 percent occurrence of pheasant egg shells. On two occasions these reptiles were observed in the nest, destroying the eggs. Crows were thought directly responsible for the loss of four nests and were secondary factors in at least three others. Desertion of the remaining four nests was attributed to the fact that they were compound clutches with no single hen as the sole incubator. In one instance, two different hens were identified attempting to incubate a single clutch at separate intervals. The two successful clutches produced a total of nine young from 17 eggs. In 1952 only one clutch of six eggs was found and it was believed deserted because of the hen's death. No attempt was made to evaluate renesting, but some such attempts probably occurred in 1951.

In 1951, 43 eggs, representing deserted clutches, unhatched eggs in successful clutches, and "dropped eggs," were examined for fertility and embryo development. Of these, 19 were classified as fertile, 6 infertile, and 18 were beyond field identification. The six eggs from the deserted clutch of 1952 were fertile. When examined, all fertile eggs contained dead embryos of a very early stage. It was entirely possible that several or all of the 18 undetermined did likewise. Temperature may have been a factor, as reported by Yeatter (1950). The infertile eggs were all found in a single nest, established on July 3, at a time when only one cock was known to be left on the island, which may account for the infertility of the eggs.

The results of the present study were doubtless influenced by the concentration of birds in a limited area, by the game-farm origin of the birds released, and by clipped wings. Increased predation, compound clutches, and intra-specific strife could well be associated with a high density. Predation on both adults and eggs must be viewed as somewhat extraordinary. Findings of Scott (1947) in Iowa indicated that fox predation was proportionately greater in marginal habitats with low pheasant populations than in good habitats with high populations. Game-farm birds would be less suited to survive than wild birds because of necessary adjustments required of them when liberated. However, so limited a study reveals the severity of the limiting factors that are imposed on a species when so far outside its established range, even when given partial protection from environmental limitations. It further indicates that not single factors, but probably a combination of several are important in evaluating the limitations imposed on stocked birds, particularly when planted beyond the fringe of their established range. When limitations are exerted on the reproductive potential of a species, they are extremely effective. The evidence of dead embryos and the loss of breeding stock suggests that these at present had the greatest influence on success.

Although the present data do not

support it, it seems reasonable that a selective breeding program might develop birds suited to conditions in southern Illinois. Such a program would logically begin with birds already adapted to more southern areas, such as those in southern California or from southern extremes in their Asiatic home. Large isolated enclosures containing natural conditions would be necessary. Rigid protection would be required to insure existence of selected birds for breeding. The practicality of such an expensive program might be questionable.

In connection with the development of a pheasant adapted to southern conditions, the compatability of pheasants and quail, *Colinus virginianus,* needs to be evaluated. It would be unwise to establish a game bird which would compete with another desirable species. Errington's (1945) studies in Iowa suggested that in winter, particularly, pheasants were present at expense of the bob-whites.

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# AVIAN POPULATIONS OF THE FUNK FOREST NATURAL AREA IN McLEAN COUNTY, ILLINOIS

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## Introduction

The purpose of this investigation was to make a detailed study of the bird population of the Funk Forest Natural Area. This paper represents a portion of the Master's Thesis (Calef, 1953a) completed under the supervision of Dr. S. C. Kendeigh. The study area is a remnant of a stream-belt type of maple-elm deciduous forest in east-central Illinois, about fifteen miles southwest of Bloomington, between the towns of Funks Grove and McLean (fig. 1). It is off U. S. Highway 66 in the southeast corner of Section 19, Funk's Grove Township, McLean County. The tract is about 2625 feet long and 1039 feet wide, an area of approximately 63 acres.

Data and detailed discussions on physical environment, local climate, and vegetation are given in Calef (1953b).

## Methods

This study began February 25, 1950, and ended November 1, 1951. Field trips were made biweekly in spring and summer seasons, weekly in autumn, and bimonthly in winter. The study area was divided into 50-meter square quadrats using a coordinate system (fig. 2).

Measurement of the bird population was based upon 82 censuses

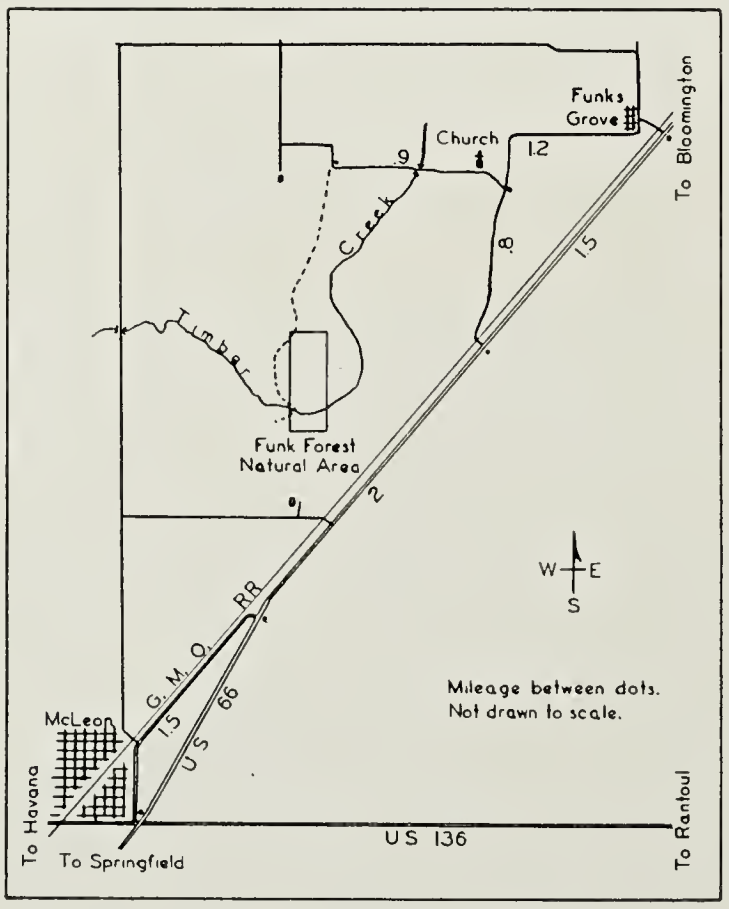


Fig. 1.—Map of the location of the Funk Forest Natural Area.

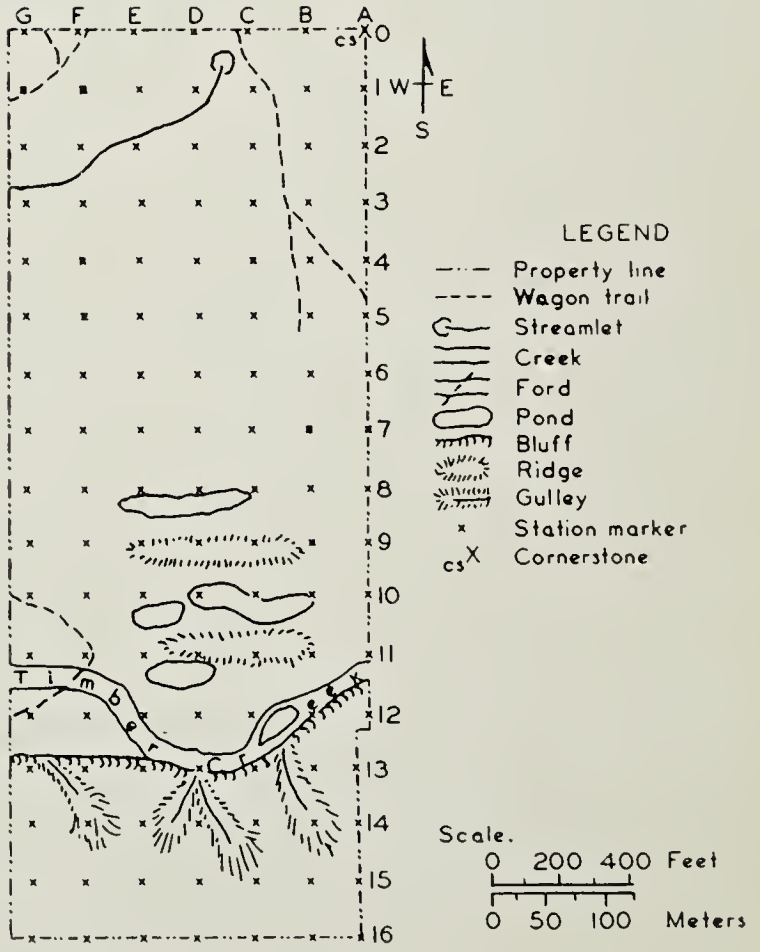


Fig. 2.—Field map of the study area.

made during the period from March 4, 1950, through July 6, 1951. Only 67 census records were satisfactory. The spot-map method (Kendeigh, 1944) was used in conjunction with census-taking routes systematically arranged to provide varied approaches into breeding territories. Territories were determined from the position of the song posts for singing males. Confirmations were based upon location of nest sites, defense zones, mated pairs, and incidence of records about loci of activity.

## Avian Population

A total of 94 species of birds in 72 genera and 28 families were recorded during 1950 and 1951 (table 1). The nomenclature is based upon that given in the A. O. U. Checklist (1931). Detailed species accounts are given in Calef (1953a). Breeding population densities were 179.3 pairs per 100 acres in 1950 and 136.5 pairs per 100 acres in 1951 (table 3). In 1950, four species, namely, alder flycatcher, Baltimore oriole, yellow-throated vireo and red-eyed towhee, were present that were not recorded in 1951. In 1951, nine additional species, namely, turkey vulture, bob-white quail, solitary sandpiper, whip-poor-will, veery, Tennessee warbler, red-winged blackbird, rusty blackbird and bronzed grackle, were present that were not recorded in 1950.

## Residential Status

The residential status for each species is noted in table 1 and a summary is given in table 2. The breeding population, comprised of permanent residents and summer residents, accounted for about one-third of the total number of recorded species. Migratory transients, birds which passed through the area but did not remain to breed, accounted for another one-third. One-third was composed of occasional visitors and winter visitors.

## Population Fluctuation

Data changes in populations of species (table 3) are illustrated in fig. 3. The number of permanent resident species remained fairly constant, although there was a decrease in winter, and an increase in spring and autumn due to local wandering. They dispersed from the study area in search of food and shelter during the winter months and returned with the onset of the breeding season.

Migratory transients and warblers contributed to the peak of species for spring migration waves, which were 61 on May 7, 1950, and 58 on May 13, 1951. These peaks built up rapidly in nine to fifteen days, and then diminished to the summer resident level in about six to nine days.

Summer resident species were superimposed upon the more or less

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Table 1.—Species List and Residential Status for Birds Recorded During 1950 and 1951

ARDEIDAE

Great Blue Heron, *Ardea herodias*. OV.[1]
American Bittern, *Botaurus lentiginosus*. OV.

ANATIDAE

Mallard Duck, *Anas platyrhynchos*. MT.
Wood Duck, *Aix sponsa*. SR.

CATHARTIDAE

Turkey Vulture, *Cathartes aura*. OV.

[1] Permanent resident (PR); summer resident (SR); migratory transient (MT); occasional visitor (OV); and winter visitor (WV).

ACCIPTRIIDAE

Red-tailed Hawk, *Buteo borealis*. PR.

PERDICIDAE

Bob-white Quail, *Colinus virginianus*. OV.

SCOLOPACIDAE

Woodcock, *Philahela minor*. OV.
Spotted Sandpiper, *Actitis macularia*. OV.
Solitary Sandpiper, *Tringa solitaria*. OV.

COLUMBIDAE

Mourning Dove, *Zenaidura macroura*. SR.

CUCULIDAE

Yellow-billed Cuckoo, *Coccyzus americanus*. SR.

STRIGIDAE

Screech Owl, *Otus asio*. OV.
Great Horned Owl, *Bubo virginianus*. PR.
Barred Owl, *Strix varia*. PR.

CAPRIMULGIDAE

Whip-poor-will, *Antrostomus vociferus*. OV.
Nighthawk, *Chordeiles minor*. MT.

TROCHILIDAE

Ruby-throated Hummingbird, *Archilochus colubris*. OV.

ALCEDINIDAE

Belted Kingfisher, *Megaceryle alcyon*. SR.

PICIDAE

Yellow-shafted Flicker, *Colaptes auratus*. PR.
Red-bellied Woodpecker, *Centurus carolinus*. PR.
Red-headed Woodpecker, *Melanerpes erythrocephalus*. OV.
Yellow-bellied Sapsucker, *Sphyrapicus varius*. MT.
Hairy Woodpecker, *Dryobates villosus*. PR.
Downy Woodpecker, *Dryobates pubescens*. PR.

TYRANNIDAE

Crested Flycatcher, *Myiarchus crinitus*. SR.
Eastern Phoebe, *Sayornis phoebe*. OV.
Alder Flycatcher, *Empidonax traillii*. OV.
Least Flycatcher, *Empidonax minimus*. OV.
Wood Pewee, *Myiochanes virens*. SR.

CORVIDAE

Blue Jay, *Cyanocitta cristata*. SR.
Crow, *Corvus brachyrynchos*. OV.

PARIDAE

Black-capped Chickadee, *Penthestes atricapillus*. PR.
Tufted Titmouse, *Baelophus bicolor*. PR.

SITTIDAE

White-breasted Nuthatch, *Sitta carolinensis*. PR.

CERTHIIDAE

Brown Creeper, *Certhia familiaris*. WV.

TROGLODYTIDAE

House Wren, *Troglodytes aedon*. SR.
Carolina Wren, *Thryothorus ludivicianus*. SR.
Winter Wren, *Nannus hiemalis*. WV.

MIMIDAE

Catbird, *Dumatella carolinensis*. OV.
Brown Thrasher, *Toxostoma rufum*. OV.

TURDIDAE

Robin, *Turdus migratorius*. SR.
Wood Thrush, *Hylocichla mustelina*. SR.
Hermit Thrush, *Hylocichla guttata*. MT.
Olive-backed Thrush, *Hylocichla ustulata*. MT.
Gray-cheeked Thrush, *Hylocichla minima*. MT.
Veery, *Hylocichla fuscescens*. OV.
Eastern Bluebird, *Sialis sialis*. OV.

SYLVIIDAE

Golden-crowned Kinglet, *Regulus satrapa*. MT.
Ruby-crowned Kinglet, *Corthylio calendula*. MT.

STURNIDAE

Starling, *Sturnus vulgaris*. OV.

VIREONIDAE

White-eyed Vireo, *Vireo grisseus*. OV.
Yellow-throated Vireo, *Vireo flavifrons*. OV.
Red-eyed Vireo, *Vireo olivaceus*. SR.
Warbling Vireo, *Vireo gilvus*. OV.

PARULIDAE

Black and White Warbler, *Mniotilta varia*. MT.
Prothonotary Warbler, *Protonotaria citrea*. MT.
Tennessee Warbler, *Vermivora peregrina*. MT.
Yellow Warbler, *Dendroica aestiva*. MT.
Magnolia Warbler, *Dendroica magnolia*. MT.

Black-throated Blue Warbler, *Dendroica caerulescens.* MT.
Myrtle Warbler, *Dendroica coronata.* MT.
Black-throated Green Warbler, *Dendroica virens.* MT.
Cerulean Warbler, *Dendroica cerulea.* MT.
Blackburnian Warbler, *Dendroica fusca.* MT.
Yellow-throated Warbler, *Dendroica dominica.* MT.
Chestnut-sided Warbler, *Dendroica pennsylvanica,* MT.
Pine Warbler, *Dendroica pinus.* MT.
Oven-bird, *Seiurus aurocapillus.* SR.
Louisiana Water-thrush, *Seiurus motacilla.* OV.
Kentucky Warbler, *Oporornis formosus.* SR.
Yellow-throat, *Geothlypis trichas.* SR.
Hooded Warbler, *Wilsonia citrina.* MT.
Canada Warbler, *Wilsonia canadensis.* MT.
American Redstart, *Sctophaga ruticilla.* SR.

ICTERIDAE

Red-wing, *Agelaius phoeniceus.* MT.
Baltimore Oriole, *Icterus galbula.* MT.
Rusty Blackbird, *Euphagus carolinus.* MT.
Bronzed Grackle, *Quiscalus quiscula.* MT.
Cowbird, *Molothrus ater.* SR.

THRAUPIDAE

Scarlet Tanager, *Piranga erythromelas.* SR.
Summer Tanager, *Piranga rubra.* MT.

FRINGILLIDAE

Cardinal, *Richmondena cardinalis.* SR.
Rose-breasted Grosbeak, *Hedymeles ludovicianus.* SR.
Indigo Bunting, *Pascerina cyanea.* SR.
Purple Finch, *Carpodacus purpureus.* MT.
Eastern Goldfinch, *Spinus tristis.* OV.
Red-eyed Towhee, *Pipilo erythropthalmus.* OV.
Slate-colored Junco, *Junco hyemalis.* WV.
Field Sparrow, *Spizella pusilla.* OV.
White-crowned Sparrow, *Zonotrichia leucophrys.* MT.
White-throated Sparrow, *Zonotrichia albicollis.* MT.
Fox Sparrow, *Passerella iliaca.* MT.
Song Sparrow, *Melospiza melodia.* OV.

TABLE 2.—SUMMARY OF THE RESIDENTIAL CLASSIFICATION OF AVIAN SPECIES

| Symbol | Classification | Species No. | Species Percent |
|---|---|---|---|
| MT | Migratory Transients | 32 | 34.1 |
| OV | Occasional Visitors... | 28 | 29.8 |
| SR | Summer Residents .. | 21 | 22.3 |
| PR | Permanent Residents | 10 | 10.6 |
| WV | Winter Visitors ..... | 3 | 3.2 |
| | Totals ..... | 94 | 100.0 |

stable permanent resident base level. They began arriving as early as February and increased to a peak in early and mid-May. The number of summer resident species declined gradually over a six and one-half month period due to nesting failure, post-breeding dispersion, and quiescence in aestival activity.

Winter visitors were present from late October through mid-April and early May. Occasional visitors wandered into and out of the study area more often in April and May than at any other time. They were not recorded in November and December.

Fluctuations in the number of individuals (table 4) corresponded with those for species (fig. 4).

Waves of migrant individuals were reflected by peaks in the spring and autumn with maximum numbers approximating 1356 per 100 acres on May 7, 1950; and 1383 per 100 acres on May 13, 1951. With them came summer residents which swelled the basic population to the breeding season peak.

## WINTER SOCIAL FLOCKS

Winter residents comprised such winter visitors as brown creepers, winter wrens, slate-colored juncos

TABLE 3.—SUMMARY OF DATA FOR 31 BREEDING SPECIES
Note: (p) present in the area

| Species | Number of Breeding Pairs | | | | 1950 Territories | | | | 1951 Territories | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | per 63 Acres | | per 100 Acres | | Number Measured | Area in Acres | | | Number Measured | Area in Acres | | |
| | 1950 | 1951 | 1950 | 1951 | | Min. | Max. | Ave. | | Min. | Max. | Ave. |
| Wood Duck | 1.0 | 1.0 | 1.6 | 1.6 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Red-tailed Hawk | 1.0 | 1.0 | 1.6 | 1.6 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Mourning Dove | 2.0 | 1.0 | 3.2 | 1.6 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Yellow-billed Cuckoo | 2.0 | 1.0 | 3.2 | 1.6 | 2 | 2.02 | 2.35 | 2.18 | 1 | .... | .... | 2.43 |
| Great Horned Owl | 1.0 | 0 | 1.6 | p | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Barred Owl | p | 1.0 | p | 1.6 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Belted Kingfisher | 1.0 | 1.0 | 1.6 | 1.6 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Yellow-shafted Flicker | 2.0 | 1.0 | 3.2 | 1.6 | 1 | .... | .... | 1.55 | 0 | .... | .... | .... |
| Red-bellied Woodpecker | 7.0 | 7.0 | 11.0 | 11.0 | 6 | 2.06 | 5.19 | 3.58 | 5 | 2.23 | 4.61 | 3.41 |
| Hairy Woodpecker | 5.5 | 7.5 | 8.7 | 11.9 | 6 | 1.63 | 3.71 | 2.54 | 7 | 1.58 | 3.30 | 2.70 |
| Downy Woodpecker | 9.5 | 5.0 | 15.1 | 7.9 | 9 | 1.26 | 3.08 | 2.05 | 4 | 1.28 | 2.09 | 1.54 |
| Crested Flycatcher | 7.0 | 6.0 | 11.0 | 9.5 | 7 | 0.61 | 2.75 | 1.46 | 6 | 2.06 | 4.64 | 3.05 |
| Wood Pewee | 9.0 | 6.5 | 14.3 | 10.3 | 8 | 1.36 | 2.94 | 1.93 | 4 | 2.38 | 3.13 | 2.70 |
| Blue Jay | 2.5 | 2.5 | 4.0 | 4.0 | 5 | 0.49 | 0.95 | 0.62 | 0 | .... | .... | .... |
| Black-capped Chickadee | 6.5 | 7.5 | 10.3 | 11.9 | 5 | 1.19 | 4.42 | 2.76 | 7 | 2.47 | 5.02 | 3.28 |
| Tufted Titmouse | 4.5 | 3.0 | 7.1 | 4.8 | 5 | 1.60 | 2.94 | 2.24 | 3 | 3.40 | 4.56 | 3.85 |
| White-breasted Nuthatch | 6.0 | 5.0 | 9.5 | 7.9 | 3 | 1.39 | 3.01 | 2.31 | 7 | 1.79 | 3.33 | 2.44 |
| House Wren | 5.0 | 2.0 | 7.9 | 3.2 | 3 | 2.43 | 2.84 | 2.69 | 1 | .... | .... | 1.00 |
| Carolina Wren | 5.5 | 2.5 | 8.7 | 4.0 | 5 | 0.71 | 1.21 | 1.02 | 2 | 1.43 | 1.62 | 1.53 |
| Robin | 1.5 | 0.5 | 2.4 | 0.8 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Wood Thrush | 8.5 | 5.0 | 13.5 | 7.9 | 7 | 1.67 | 4.27 | 3.17 | 4 | 2.43 | 3.23 | 2.81 |
| Red-eyed Vireo | 5.0 | 4.0 | 7.9 | 6.3 | 4 | 0.58 | 2.53 | 1.43 | 4 | 1.92 | 2.60 | 2.36 |
| Oven-bird | 8.5 | 5.5 | 13.5 | 8.7 | 8 | 1.33 | 4.61 | 2.51 | 5 | 2.82 | 5.47 | 4.11 |
| Kentucky Warbler | 1.0 | 0.5 | 1.6 | 0.8 | 1 | .... | .... | 2.52 | 0 | .... | .... | .... |
| Yellow-throat | 2.0 | 1.0 | 3.2 | 1.6 | 2 | 0.48 | 1.46 | 0.97 | 1 | .... | .... | 0.71 |
| American Redstart | 1.0 | p | 1.6 | p | 1 | .... | .... | 3.20 | 0 | .... | .... | .... |
| Cowbird | p | p | p | p | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Scarlet Tanager | 1.0 | 1.5 | 1.6 | 2.4 | 1 | .... | .... | 1.58 | 1 | .... | .... | 2.74 |
| Cardinal | 2.5 | 1.5 | 4.0 | 2.4 | 0 | .... | .... | .... | 0 | .... | .... | .... |
| Rose-breasted Grosbeak | 3.0 | 3.5 | 4.8 | 5.6 | 2 | 1.79 | 1.89 | 1.84 | 2 | 1.97 | 2.47 | 2.22 |
| Indigo Bunting | 1.0 | 1.5 | 1.6 | 2.4 | 1 | .... | .... | 2.72 | 0 | .... | .... | .... |
| Totals | 113.0 | 86.0 | 179.3 | 136.5 | 92 | | | | 64 | | | |

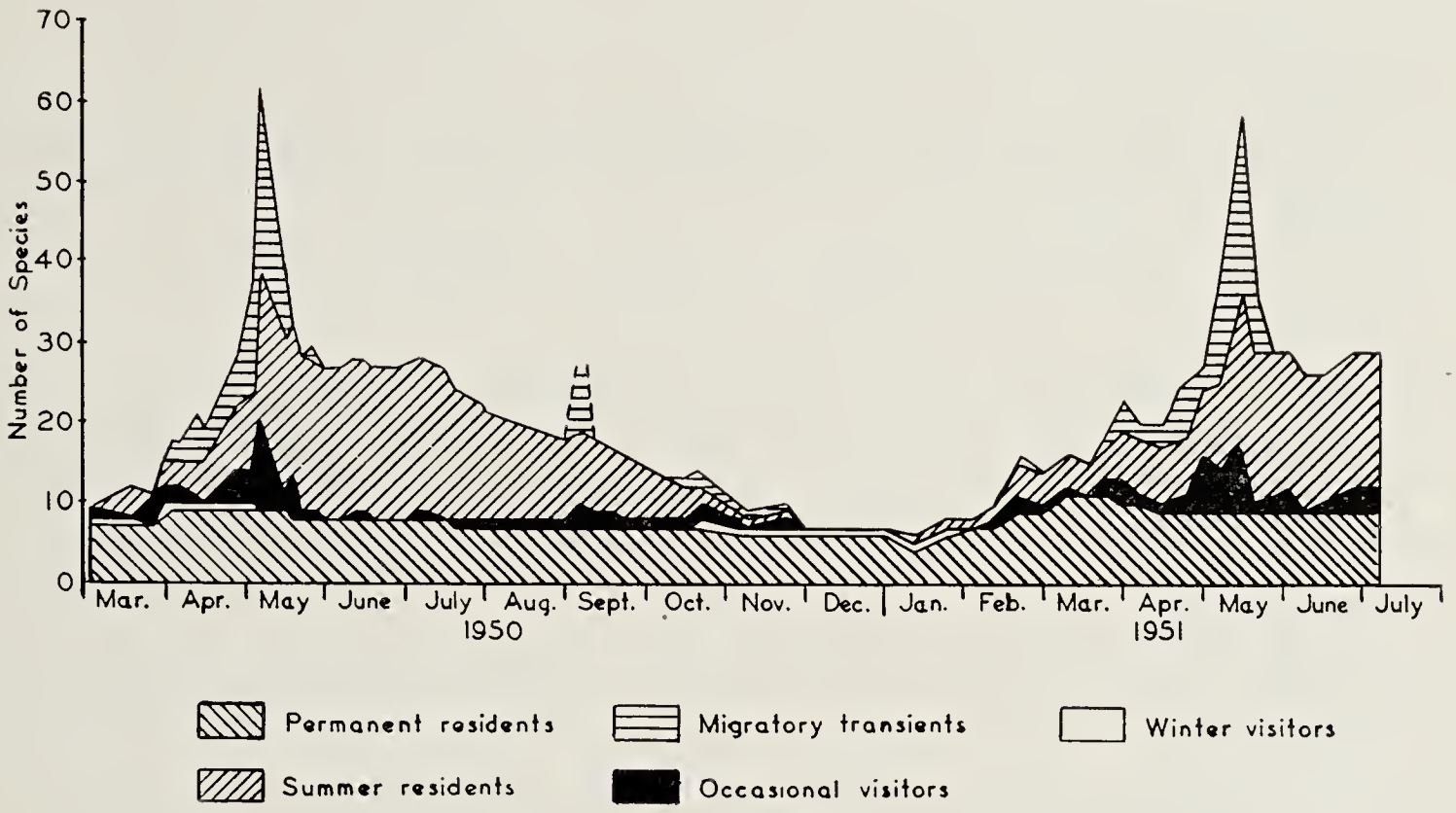


FIG. 3.—Fluctuations in number of species during 1950 and 1951. The open, broken-line peak in September indicates that data were incomplete.

and the group of permanent resident species. Red-bellied woodpeckers, downy woodpeckers, hairy woodpeckers, black-capped chickadees, tufted titmice, white breasted nuthatches and brown creepers began congregating into winter social groups by mid-November (fig. 5). Woodpeckers appeared to be the leaders, the red-bellied woodpecker being the despotic one when present. Feeding was the chief activity and call notes were uttered frequently. Chickadees, titmice, nuthatches, and brown creepers followed the woodpeckers from tree to tree, apparently having learned that they would benefit where woodpeckers found food. Brown creepers were usually at the periphery of group activity or by themselves a short distance away. Since these birds were not banded, it was not known whether or not the same individuals composed each flock throughout the winter season.

The flocks began to disband in mid-February when woodpeckers began territorial and mating activities. Brown creepers were next to leave for northward migration. Other members of the winter flocks seemed to break away in no definite order. Nuthatches and tufted titmice remained together the longest time.

## Effect of Winds Upon Bird Distribution

Determinations of the effect of wind velocity and direction upon bird distribution within the study area were made throughout seasonal stages of forest tree foliation (table 5). Percentages of foliation were based upon a method of subjective measurement and observation. Foliage conditions in the winter were considered as barren, which was less than 1 percent but not 0 percent because oaks and hornbeams held withered leaves until early spring. The appearance of bursting leaf buds and

TABLE 4.—BIRD CENSUS DATES AND NUMBERS RECORDED

| Date | Number of Species Per 63 Acres | Number of Individuals Per 63 Acres | Number of Individuals Per 100 Acres |
|---|---|---|---|
| 1950: | | | |
| Mar.: 4 | 9 | 48 | 76 |
| 19 | 12 | 244 | 387 |
| 27 | 11 | 35 | 56 |
| 29 | 16 | 228 | 362 |
| Apr.: 2 | 18 | 135 | 214 |
| 5 | 17 | 98 | 156 |
| 12 | 22 | 339 | 538 |
| 16 | 19 | 79 | 125 |
| 19 | 21 | 102 | 162 |
| 26 | 28 | 266 | 422 |
| May: 3 | 37 | 456 | 724 |
| 7 | 61 | 854 | 1356 |
| 14 | 39 | 712 | 1130 |
| 17 | 34 | 556 | 883 |
| 21 | 28 | 260 | 413 |
| 24 | 29 | 269 | 427 |
| 28 | 27 | 265 | 420 |
| 31 | 28 | 266 | 422 |
| June: 4 | 27 | 256 | 406 |
| 7 | 27 | 247 | 392 |
| 11 | 28 | 258 | 410 |
| 14 | 28 | 235 | 373 |
| 18 | 27 | 241 | 383 |
| 21 | 27 | 234 | 371 |
| 25 | 27 | 213 | 338 |
| July: 7 | 28 | 209 | 331 |
| 16 | 27 | 218 | 346 |
| 20 | 24 | 181 | 287 |
| 29 | 22 | 148 | 235 |
| Aug.: 4 | 21 | 111 | 176 |
| 11 | 20 | 94 | 149 |
| Sept.: 1 | 18 | 83 | 132 |
| 6 | 20 | 107 | 170 |
| 11 | 18 | 52 | 83 |
| Sept.: 17 | 17 | 60 | 95 |
| 24 | 16 | 55 | 87 |
| Oct.: 15 | 13 | 34 | 54 |
| 20 | 14 | 66 | 105 |
| Nov.: 10 | 9 | 45 | 71 |
| 24 | 10 | 31 | 49 |
| Dec.: 1 | 7 | 21 | 33 |
| 19 | 7 | 19 | 30 |
| 29 | 7 | 27 | 43 |
| 1951: | | | |
| Jan.: 11 | 6 | 20 | 32 |
| 25 | 8 | 23 | 37 |
| Feb.: 6 | 8 | 30 | 48 |
| 11 | 10 | 30 | 48 |
| 22 | 16 | 100 | 159 |
| Mar.: 1 | 14 | 75 | 119 |
| 8 | 16 | 74 | 117 |
| 18 | 15 | 56 | 89 |
| 23 | 18 | 90 | 143 |
| 29 | 23 | 107 | 170 |
| Apr.: 1 | 19 | 335 | 532 |
| 7 | 20 | 121 | 192 |
| 15 | 20 | 112 | 178 |
| 23 | 24 | 136 | 216 |
| 29 | 27 | 193 | 306 |
| May: 6 | 38 | 461 | 732 |
| 13 | 58 | 871 | 1383 |
| 19 | 36 | 339 | 538 |
| 26 | 29 | 233 | 370 |
| June: 3 | 29 | 206 | 327 |
| 10 | 26 | 183 | 290 |
| 16 | 26 | 183 | 290 |
| 27 | 29 | 189 | 300 |
| July: 6 | 29 | 187 | 297 |

TABLE 5.—WIND AND FOLIATION DATA AFFECTING BIRD DISTRIBUTION

| Date | Percentage of tree Foliation | Velocity MPH | | Prevailing Direction | Bird Distribution |
|---|---|---|---|---|---|
| | | Sta. A in Open Country | Sta. B Within Forest | | |
| 1950: | | | | | |
| Mar. 19 | barren | 20 | 15-20 | NE | SW corner |
| Mar. 27 | barren | 20 | 20 | NW | SW corner |
| Mar. 29 | barren | 2 | 0- 1 | W | forest-wide |
| Apr. 2 | barren | 25 | 20 | S | forest-wide |
| Apr. 5 | barren | 2 | 2 | NE | forest-wide |
| Apr. 12 | barren | 15 | 12 | NW | forest-wide |
| Apr. 16 | barren | 12 | 11 | W | forest-wide |
| Apr. 19 | barren | 8 | 2 | W | forest-wide |
| Apr. 26 | barren | 5 | 3 | W | forest-wide |
| May 3 | 25% foliated | 6 | 0- 1 | W | forest-wide |
| May 7 | 75% foliated | 6 | 2 | E | forest-wide |
| May 10 | 95% foliated | 2 | 0- 1 | E | forest-wide |
| May 14 | 100% foliated | 15-18 | 5- 8 | S | forest-wide |
| May 21 | 100% foliated | 5 | 0- 1 | W | forest-wide |
| June 4 | 100% foliated | 10-15 | 4 | NW | forest-wide |
| July 12 | 100% foliated | 5-10 | 1- 3 | S | forest-wide |
| Sept. 17 | 100% foliated | 12 | 4- 6 | E | forest-wide |
| Oct. 15 | 95% foliated | 0-15 | 0- 4 | E | forest-wide |
| Oct. 20 | 25% foliated | ..... | 0- 4 | W | forest-wide |
| Nov. 10 | barren | ..... | 4 | W | E & S margins |
| Nov. 24 | barren | ..... | 8 | NE | SW corner |
| Dec. 1 | barren | ..... | 5 | E | SW & W margins |
| Dec. 19 | barren | ..... | 7 | NE | E margin |
| Dec. 29 | barren | ..... | 5 | E | W & SW margins |
| 1951: | | | | | |
| Jan. 11 | barren | ..... | 5 | E | W margin |
| Jan. 25 | barren | 0 | 0 | 0 | SW corner |
| Feb. 6 | barren | ..... | 0- 1 | NW | E margin |
| Feb. 11 | barren | ..... | 20 | NW | S & SE margins |
| Feb. 22 | barren | 0 | 0 | 0 | forest-wide |
| Mar. 1 | barren | ..... | 2 | W | forest-wide |
| Mar. 8 | barren | ..... | 2 | W | forest-wide |
| Mar. 18 | barren | 30-40 | 30 | W | Refer to text. |
| Mar. 23 | barren | 10 | 8 | SW | W & NW margins |
| Mar. 29 | barren | 10 | 3 | SW | forest-wide |
| Apr. 1 | barren | 15 | 14 | W | forest-wide |
| Apr. 7 | barren | 3 | 0- 1 | W | forest-wide |
| Apr. 15 | barren | 16 | 14 | W | forest-wide |
| Apr. 23 | barren | 10 | 3 | NW | forest-wide |
| Apr. 29 | barren | 2 | 0- 1 | W | forest-wide |
| May 6 | 25% foliated | 10 | 5-10 | W | forest-wide |
| May 13 | 75% foliated | 3 | 0- 1 | SE | forest-wide |
| May 19 | 95% foliated | 2 | 0- 1 | E | forest-wide |
| May 26 | 100% foliated | 25 | 4 | W | forest-wide |
| June 3 | 100% foliated | 3 | 0- 1 | SW | forest-wide |
| June 27 | 100% foliated | 10-15 | 6 | SW | forest-wide |
| July 6 | 100% foliated | 3 | 0- 1 | SE | forest-wide |

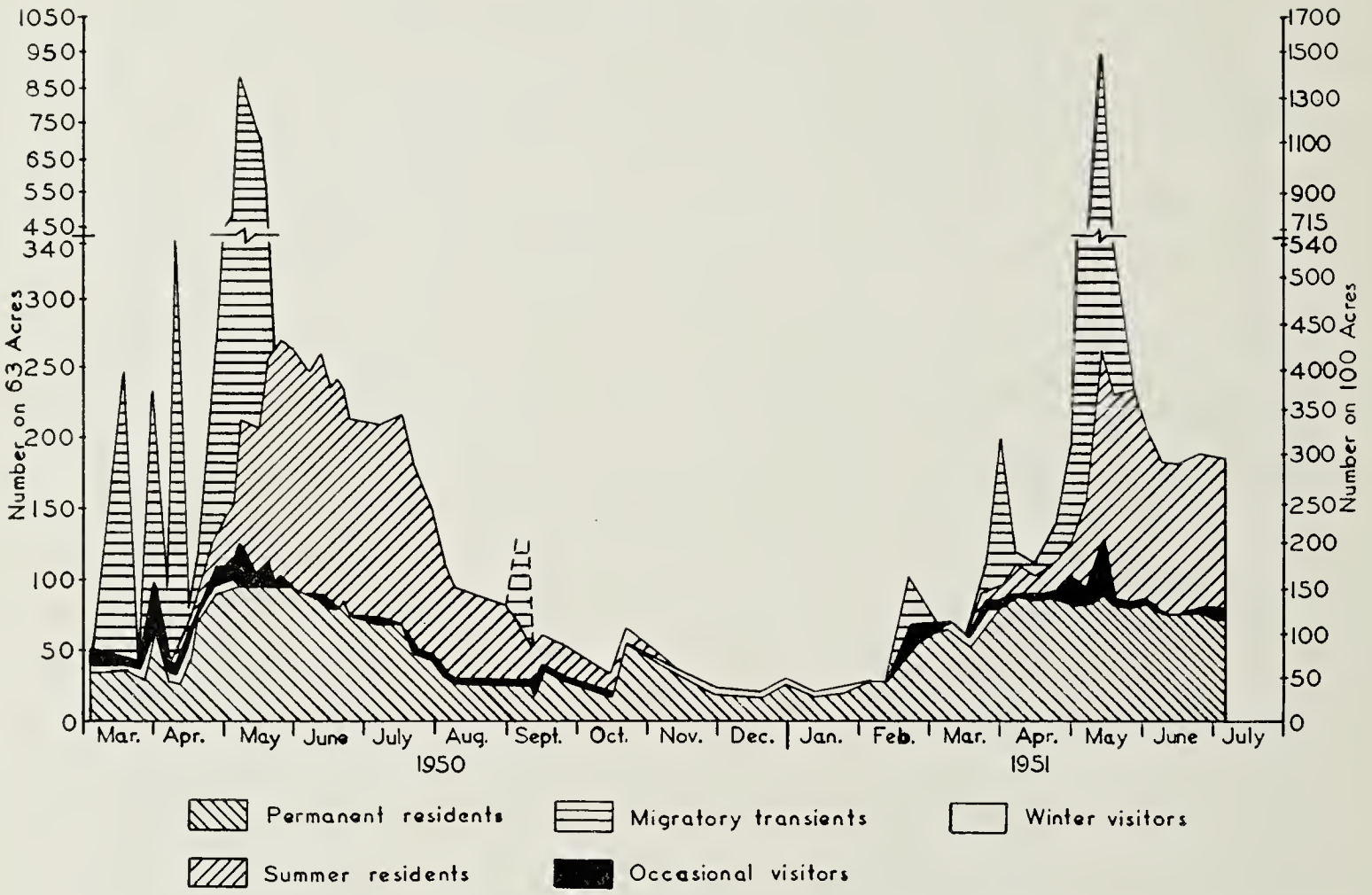


FIG. 4.—Fluctuations in number of individuals during 1950 and 1951. The open, broken-line peak in September indicates data were incomplete.

leaflets was considered as 25 percent foliated. As leaf growth progressed and the crown mass became more dense, the forest was considered as 75 percent foliated. Since oaks and hickories did not reach full foliage until later than other species, the late vernal forest was considered only 95 percent foliated. The condition of 100 percent foliation was reached only after all trees were in full mature leaf, which then persisted throughout the summer and into the autumn.

In 1950, trees began leafing about May 1, reaching complete foliation by May 14. Defoliation began about October 15 and reached the winter barren condition by November 10. In 1951, foliation began May 3 and reached its completion about May 21. No observations were made for the autumn of 1951.

Wind directions and velocities were measured with a hand anemometer held six feet high. Readings were taken at several stations. For velocities of unobstructed winds, readings were taken in open country on the windward side of the study area. These locations are grouped together under the designation, Station A. For velocities of winds obstructed by trees, measurements were taken within the forest either on the lee side or in the center at D-6 (fig. 2) where the weather instruments were situated. These were grouped together under the heading, Station B.

Distribution of birds was based upon sight and song records indicating locations of individual birds. Of particular importance were observa-

tions of flocks or such signs of bird groupings that might indicate massing together.

Only critical data are given in table 5 since the majority of the summer records showed no evidence for winds affecting bird distribution. Comparison of wind velocities between open country and within the forest shows that velocities are reduced less when trees are barren than when they are foliated. Reductions during the barren period range from 0 to 70 percent, with an average of 27 percent. During the foliated period, reductions range from 67 to 84 percent, with an average of 71 percent.

A significant factor at the time of recording was wind force variability, i.e., whether gusty or steady. This variability produced considerable differences between records taken in the open and those inside the forest. In general, it appeared to be a cumulative effect of continuous winds which caused the birds to congregate in the lee of the forest rather than gusts of moderate velocities.

An interesting exception to this general response of birds to winds was observed March 18, 1951, at 1:30 P.M. Several flocks of birds, composed of downy woodpeckers, hairy woodpeckers, red-bellied woodpeckers, black-capped chickadees, tufted titmice, brown creepers and slate-colored juncos, were feeding high in the tree tops and snags found in the slash timber at the western side of the study area. A 30 m.p.h. west wind blew with gusts up to 40 m.p.h. The sun was obscured by clouds. The temperature had dropped from 39°F to 27°F in the course of three hours. Yet these birds continued to feed in the full force of the strong cold winds.

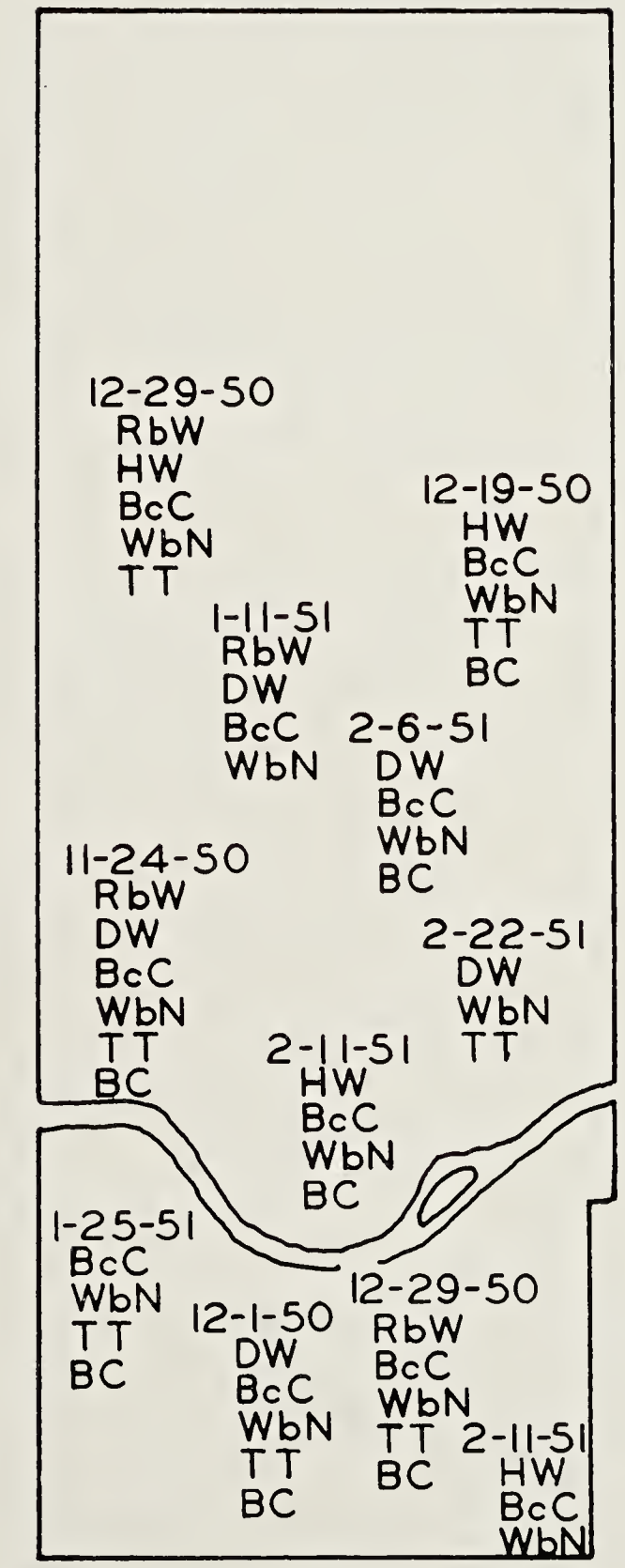


Fig. 5.—Position and composition of eleven winter social flocks.

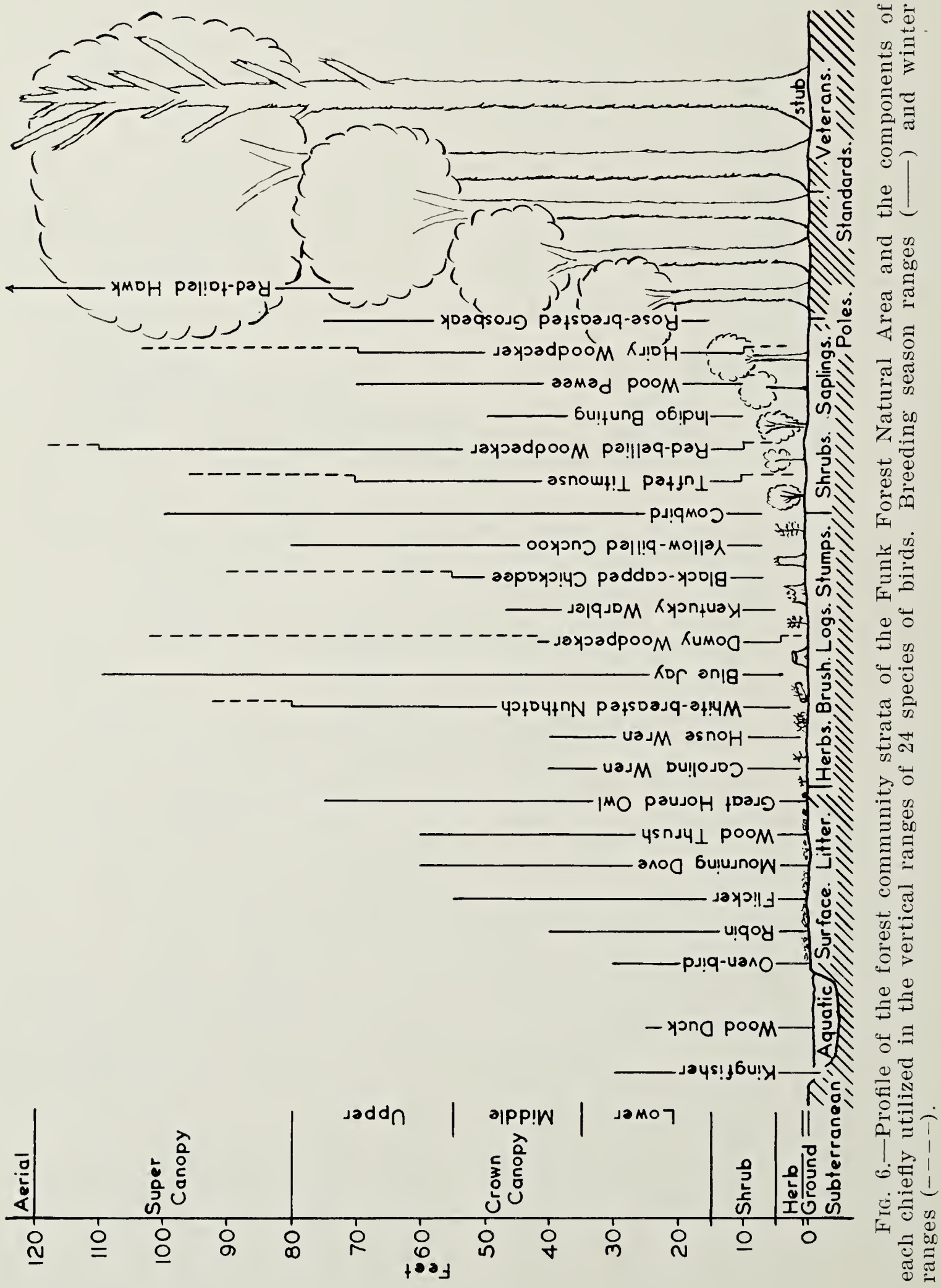


FIG. 6.—Profile of the forest community strata of the Funk Forest Natural Area and the components of each chiefly utilized in the vertical ranges of 24 species of birds. Breeding season ranges (——) and winter ranges (– – – –).

There were no birds in the forest where they usually sought shelter under less severe conditions. By using lineman's pole climbers, the writer scaled trees and examined the bark. Unsheltered trees revealed sluggishly active insects that had been warmed to life by mild temperatures and the bright sun during the previous three or four days. But insects in sheltered trees in the forested area were not active. It was concluded that the birds sought food where the supply was abundant in preference to seeking shelter during adverse weather conditions.

Other exceptions to winds affecting the distribution of forest species were observed in early spring before the trees produced leaves. With the onset of migration, territorial establishment, and mating, the rate of wind velocities had no apparent effect upon bird distribution. Their responses were much like those observed when complete foliation acted as a barrier. It was concluded that the innate desire to mass together for migration, to defend individual territories, and to mate may be more intense than the desire to seek shelter from strong winds.

## Vertical Ranges and Spatial Units

By means of classification systems and systematic observations, a method was devised for use in life history studies and the analysis of data pertinent to niche requirements of birds.

The niche is here considered to be the prime part or "core" of the habitat which is essential for continued survival of members of a species (Linsdale, 1946). It is the smallest local distributional unit of space that is occupied and utilized by the species. The niche involves the life habits of the animal. It includes the manner in which the animal responds to the biological and physical elements of its external environment. This behavioral response is governed by inherent characteristics that are determined by such internal forces as morphological, physiological, psychological and hereditary factors.

The first approach for the isolation of niches, or spatial units, was the classification of the plant strata so that vertical ranges utilized by birds could be identified. The second step was the classification of microhabitats in order to facilitate recognition of the sites most often frequented by birds. Third, life habit activities were classified for the determination and correlation of behavior at microhabitat sites within the plant community structure.

Strata for this deciduous forest community are diagrammed in fig. 6. A brief description of each follows. (1) The subterranean stratum was that part of the earth below the surface of the soil. (2) The aquatic stratum was the free body of water. (3) The ground stratum was the surface of the soil, including the litter and humus. (4) The herb stratum was varied from 3 to 5 feet high, depending upon the height of the component herbaceous plants. (5) The shrub stratum included the crown mass of small trees and shrubs from 5 to 15 feet high. (6) The crown canopy stratum was characterized by the general level of the tree canopy from 20 to about 80 feet. (7) The super canopy stratum was composed of veteran trees, of which the living crowns or dead upper structures ex-

tended to distinctive heights above the crown canopy. (8) The aerial stratum was the free air above the crown canopy and into which components of the super canopy extended.

All air space below the aerial stratum was considered sub-aerial with designation identified by the stratum concerned. Erect stems that projected through successive strata were not subdivided but were considered as portions of microhabitats.

Such life habit responses as nesting, defense, feeding and shelter-seeking showed greatest intensity about the following sites: (1) nest sites, (2) advertizing sites, (3) feeding sites, and (4) shelter sites. Life habit responses, which varied for different species in regard to both duration and intensity, were confined within vertical range limits. The vertical ranges for 24 species were determined during both the breeding and non-breeding seasons. These data, in addition to those for horizontal territorial limits, may serve to identify the spatial unit of volume utilized by a given species in its niche.

Spatial units were found to be flexible, fluctuating in shape and volume for different species and with variation in seasonal activities. General population pressures influenced the limits of size and range on a long term, breeding season basis. Intra-specific territorial conflict caused short term changes during the breeding season.

During the non-breeding season, life habit activities were not restricted to former breeding season spatial units. During the post-breeding period, vertical ranges contracted and horizontal ranges expanded as a result of parental care of fledglings. During the remainder of the non-breeding season, both vertical and horizontal ranges were greatly expanded as birds wandered in search of food and shelter.

Computation of total spatial volumes, the characteristics of the spatial units, and the description of micro-environmental factors encompassed by them have been omitted until better techniques and mathematical calculations are developed for more accurate measurement.

### Territorial Areas

Territories which had nest sites within the study area numbered 136 in 1950 and 117 in 1951. Since about 15 percent in 1950, and 18 percent in 1951, had ranges that extended outside the boundaries of the tract, only 156 territorial areas for 22 breeding species could be measured with a polar planimeter (table 3). Also, since these measurements were based upon records of approximated positions of territorially singing males, the results are general and only indicate relative territorial sizes.

The following analysis is made for 22 breeding species which had 92 measurable territories in 1950. The smallest territories were made by the yellow-throat. The largest were made by the red-bellied woodpeckers. The least range between the smallest and the largest sizes was found for rose-breasted grosbeaks, while the greatest was for the oven-birds.

In 1951, 17 species had 64 measurable territories. The smallest was again made by the yellow-throat. The largest territories were made by the oven-birds rather than by the red-

bellied woodpeckers. However, the latter species had nearly the same average size for both years. The least range between extreme sizes was found for the Carolina wren, while the greatest was for the oven-birds.

Evidence from field observations and measurements of territories indicated that, when one year is compared with the next, species of birds may be grouped into the following categories. (1) When a decrease occurred in the population size for a given species, there was a corresponding increase in the average territorial size, and a decrease in the range between extreme limits of their sizes. This was noted for wood pewees, white-breasted nuthatches, tufted titmice, Carolina wrens, red-eyed vireos and oven-birds. These changes indicated that intra-specific competition was reduced. (2) Negligible changes in population size, average territorial size, and range between extreme size limits for a given species may indicate optimum territorial sizes as controlled by normal population pressures. This was noted for yellow-billed cuckoos, red-bellied woodpeckers and rose-breasted grosbeaks. (3) Changes occurred that could not be logically explained, indicating discrepancies owing either to census and recording techniques, or other factors such as redistribution of some territories on account of renesting attempts, territorial overlap, and excessive competitive pressure.

Illustrations of conflict due to population pressure, and territorial proximity and overlap were more obvious in 1950 than in 1951. Competition was keen among red-bellied woodpeckers, especially between two males which had overlapping territories (fig. 7). As a result, one pair shifted their post-breeding range southward in order to avoid continued rivalry.

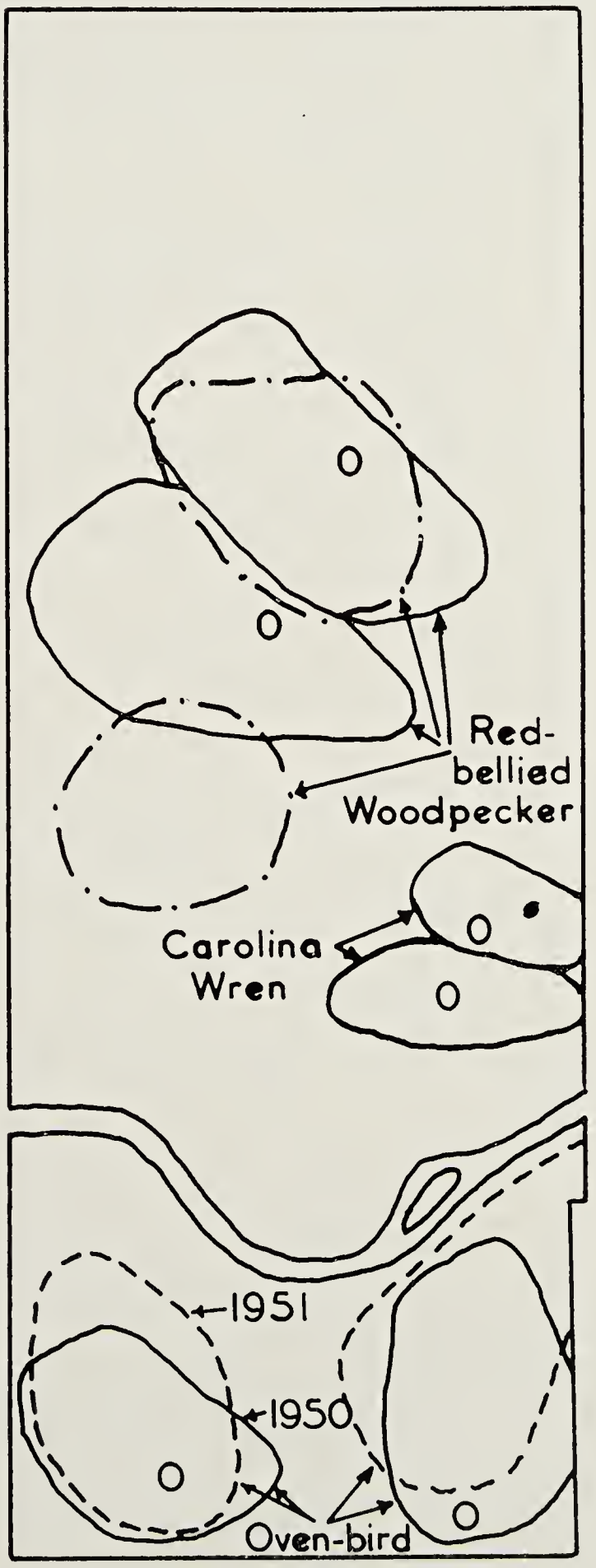


Fig. 7.—Breeding territories for red-bellied woodpeckers, oven-birds and Carolina wrens.

Proximity of wood pewee territories created more frequent conflicts during 1950 than 1951 (fig. 8). On two occasions fighting was so bitter that the writer picked up the downed contestants and found them exhausted. When they recovered, they returned to their respective territories. These two were later observed fighting many times.

Overlap of two Carolina wren territories caused considerable conflict between males (fig. 7). Singing, posturing and combat were frequent and intense. Nest sites were about 80 feet apart. The birds appeared to be cautious about entering their nests while their neighbors were either nearby or singing. When one male came close and sang, the other flew at him scolding and posturing. This behavior was not exhibited if singing was at a distance.

Singing displays were most frequent between the oven-bird males occupying the two territories south of Timber Creek (fig. 7). They sang alternately for long periods of time. This pattern was heard again in 1951 from these same areas which suggested that the same males may have returned to their original territorial sites.

When the territories are plotted for two years, some are found to be superimposed upon areas used the previous year. This may indicate that certain individuals return and occupy the same general location from one year to the next. There was some certainty that in 1951 a crested flycatcher, two wood pewees, several white-breasted nuthatches, three house wrens, a yellow-throat and two oven-birds may have returned to their 1950 territorial sites. In addition, there was likelihood that some hairy woodpeckers, downy woodpeckers, red-bellied woodpeckers, black-capped chickadees and wood

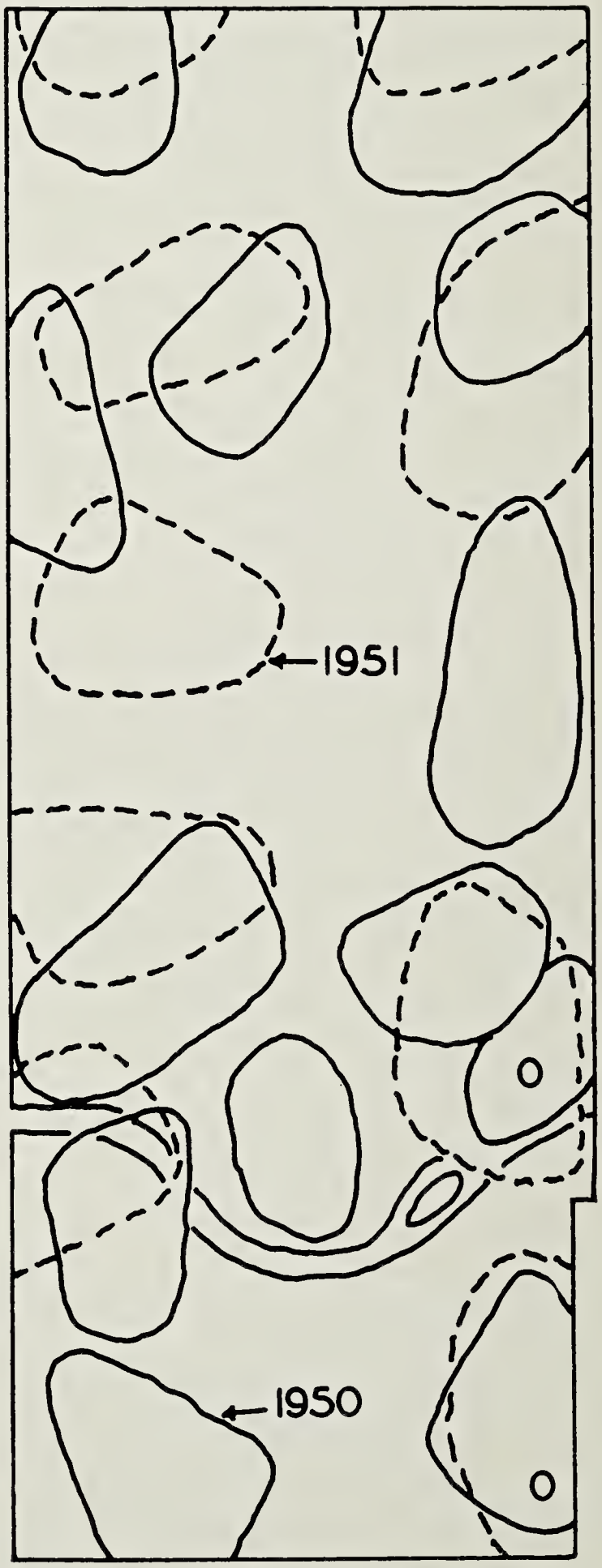


Fig. 8.—Breeding territories for wood pewees.

thrushes returned to former locations (Calef, 1953a). However, since the birds were not banded, it is impossible to be certain that it was the same male present each year.

The fact that some individuals may also hold to their breeding territories or ranges after one would usually expect them to be abandoned seems to be clearly illustrated by the red-bellied woodpeckers (fig. 9). Post-breeding ranges were remarkably coincident with the breeding territories for six birds.

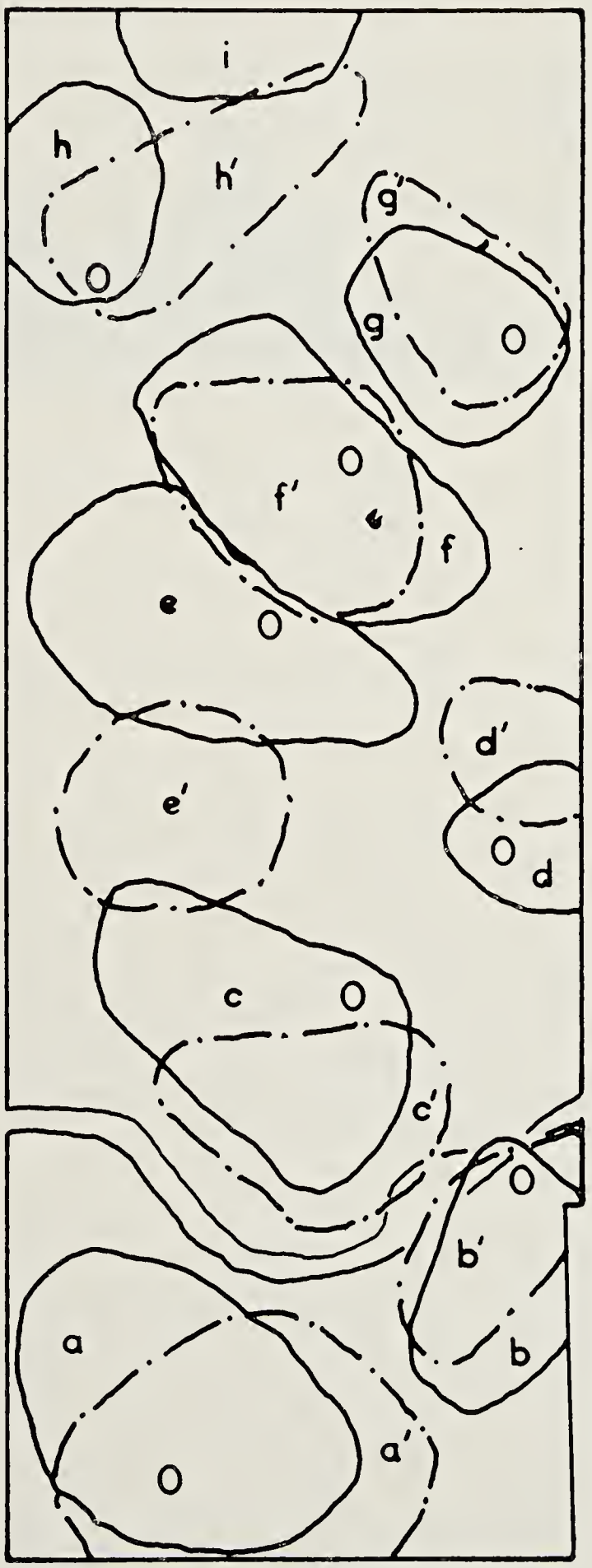


FIG. 9.—Breeding territories and post-breeding ranges for red-bellied woodpeckers during 1950.

## SEASONAL SONG RHYTHM

Observations and records of singing male birds on territories indicated daily variations in intensity and frequency which showed a cumulative seasonal rhythm. The comparison of singing with other activity records that confirmed the presence of the male on its territory is illustrated in fig. 10. March and early April data were unclassified prior to the beginning of this particular investigation.

The singing activity increased to a peak by mid-May as territorial activity reached its height. Its decline reflects the period of caring for the brood which merges with the post-breeding period of song quiescence. The two upswings in late June and mid-July is the result of renewed singing by previously quiet birds. Singing frequency for males did not keep pace with their total territorial activities, that is, although they were present on their territories, they did not sing continuously. The decline in the breeding activity curve reflects dispersion, song quiescence, and the aestival reduction of general activity as territories were abandoned. Song activity during the autumn and winter months was difficult to classify. Activities were not territorial and, therefore, songs and call notes for-

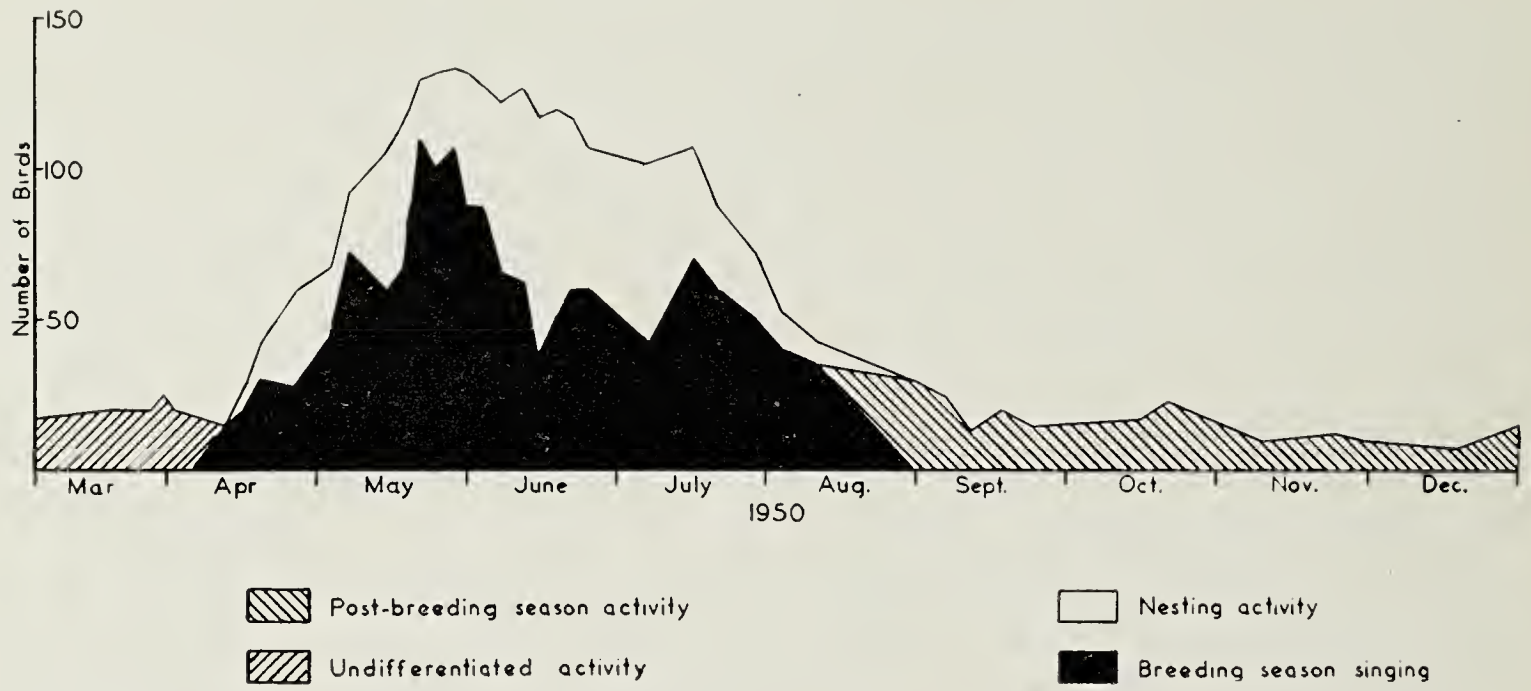


FIG. 10.—Comparison of fluctuations in singing activity with nesting activity.

merly associated with breeding season displays served different functions.

## SUMMARY AND CONCLUSIONS

Birds include 94 species in 72 genera and 28 families. Breeding population density for 1950 was 179.3 pairs per 100 acres, and for 1951, it was 136.5 pairs per 100 acres. One-third of the total number of species comprised the breeding population, one-third were migratory transients, and one-third were occasional visitors and winter visitors.

The annual species population included permanent resident species plus groups of summer residents, migratory transients, occasional visitors, and winter visitors. The fluctuation in number of individuals corresponded with that for species. Winter social flocks were usually composed of seven species, which apparently formed in response to some social bond or mutual beneficial relationship such as food-getting.

Moderately high wind velocities usually affected bird distribution in winter when the foliage was gone, but they had no apparent effect when demands for feeding, mating, defending territories, and preparing for migration were dominant. Winds had no effect when tree foliage reduced the force of the wind.

Eight major plant strata were identified in this community and their utilization by 24 species of birds was recorded. It is suggested that the spatial unit of volume determined by measurement of the vertical ranges and horizontal areas may be useful in describing the microhabitats characteristic for a given species.

Measurements of 156 territories indicate that annual variations in areal size and ranges between extreme size limits may be a function of population pressure and aggregation to hold territories. Some individuals may have returned to their former territorial areas the next breeding season. Red-bellied woodpeckers retained their former breeding territories during the immediate post-breeding period. Seasonal rhythm for singing males occurs with variations in breeding and territorial activities.

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# TRAPPING AND MARKING SQUIRRELS ON A REFUGE IN SOUTHERN ILLINOIS

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A population of fox squirrels (*Sciurus niger rufiventer* [Geoffroy]) and gray squirrels (*Sciurus carolinensis carolinensis* Gmelin) in an area of Crab Orchard National Wildlife Refuge was studied beginning in September, 1951. Southern Illinois University and the Refuge Division of the United States Fish and Wildlife Service cooperated in the two-year project.[1] The research, which included analysis of data from controlled hunting together with year-around life studies of the squirrels, was aimed toward better management of these species. The squirrels on selected sites were trapped alive, marked and released; this formed a great part of the field work throughout the year. Trapping studies began on January 8, 1952 and ended March 31, 1953. Over this 15-month period, 200 animals, composed of 99 fox squirrels and 101 gray squirrels were handled.

## Techniques

The trap used in these studies was of the type used by Baumgartner (1940) to study fox squirrels in Ohio. The device was similar to the ordinary box trap, but it was modified for use with squirrels in that the working parts were completely enclosed within the trap. Shelled corn was used as bait. To make it easy to handle and mark the squirrels they were confined in a small wire cone. Both ears were tagged with a No. 3 fingerling tag, and the outer toe of the left hind foot was marked by ringing the digit with a No. 8 monel band (manufactured by National Band and Tag Company of Newport, Kentucky). Of fifty-three recovered animals, 11 had lost one ear tag each, five had lost both ear tags. The squirrels amputated nearly all marked toes despite efforts to make the band as loose as possible.

Sixty-five traps were permanently established in six study woodlots which were designated as A, B, C, D, E, and F. The areas were selected on the basis of diversification in habitat, workable size, and accessibility. Traps were checked once daily or every other day when success was poor.

Forty-nine of 200 live-trapped squirrels were recaught from one to five times each. Of these, 34 were handled twice each, 12 three times, two four times, and one six times.

## Species Ratio

Live-trapping revealed the species ratio of 200 animals to be 50.5 percent gray squirrels and 49.5 percent fox squirrels. The species ratio of 888 squirrels taken during controlled hunting in 1951 and 1952 was nearly 60 percent gray squirrels and 40 percent fox squirrels. The balanced population of fox and gray squirrels as shown by live-trapping probably

[1] Cooperative Wildlife Studies Grant, Southern Illinois University, Carbondale, Illinois.

was a true picture for the relatively small woodlots studied. Hunters worked over large continuous timber tracts where they killed proportionately fewer fox squirrels.

## Age and Sex Ratios

Age ratios of squirrels in the fall population of 1952, as determined by trapping, showed high success in reproduction and rearing young during the season. The trapping period of October 4 through December 10 yielded 57 gray squirrels 61.4 percent of which were young, and 76 fox squirrels of which 55.2 percent were young. As squirrel activity and trapping success decreased through late November and early December, adults were captured more often than young. Not until the middle of the following April did young animals again appear in numbers. The appearance of these first-season young coincided with an increased catch of lactating females and an over-all upward trend in squirrel activity.

Although large numbers of squirrels from controlled hunting indicated that females were more abundant than males in the fall population of 1952, the numbers trapped showed that males were taken more often. Adult females were rarely caught during the breeding season and early rearing period, but trapping returns showed a gradual increase in adult females from January through May. Goodrum (1940), in studies of gray squirrels in Texas, found that breeding females have such seclusive habits that it is difficult to arrive at precise breeding seasons for this species.

## Seasonal Activity and Travel Range

Activity highs and lows were measured by the total monthly numbers of original captures and recaptures of squirrels. The fall or mast season activity peak was most pronounced with a second peak occurring during March and April (fig. 1). Low activity periods were indicated for mid-summer and midwinter. This extreme seasonal variation in activity made it difficult to get year-around data on breeding habits and information as to sex and age ratio. Activity peaks seemed to be connected with the post-breeding periods, optimum temperatures conducive to movement, and to the periods of greatest food abundance. Baker (1944) made intensive time-area counts of the gray species in Texas and found similar activity peaks which he believed to be associated with abundance of food.

The travel range of marked squirrels was studied by recording trap numbers of initial and subsequent captures. The movements of 49 animals, 25 gray squirrels and 24 fox squirrels, were followed in this manner. Periods between captures varied from two days to 11 months. Travel ranged from none at all to one-half mile. Fox squirrels ranged farther than gray squirrels. Adult fox squirrels had an average travel range of 143.9 yards, but adult gray squirrels averaged only 84.0 yards. In the same way, young fox squirrels averaged 103.3 yards, and young of the gray species only 92.0 yards.

Adult male squirrels ranged farther than adult female animals. Although adult male fox squirrels moved an average of 188.1 yards, the

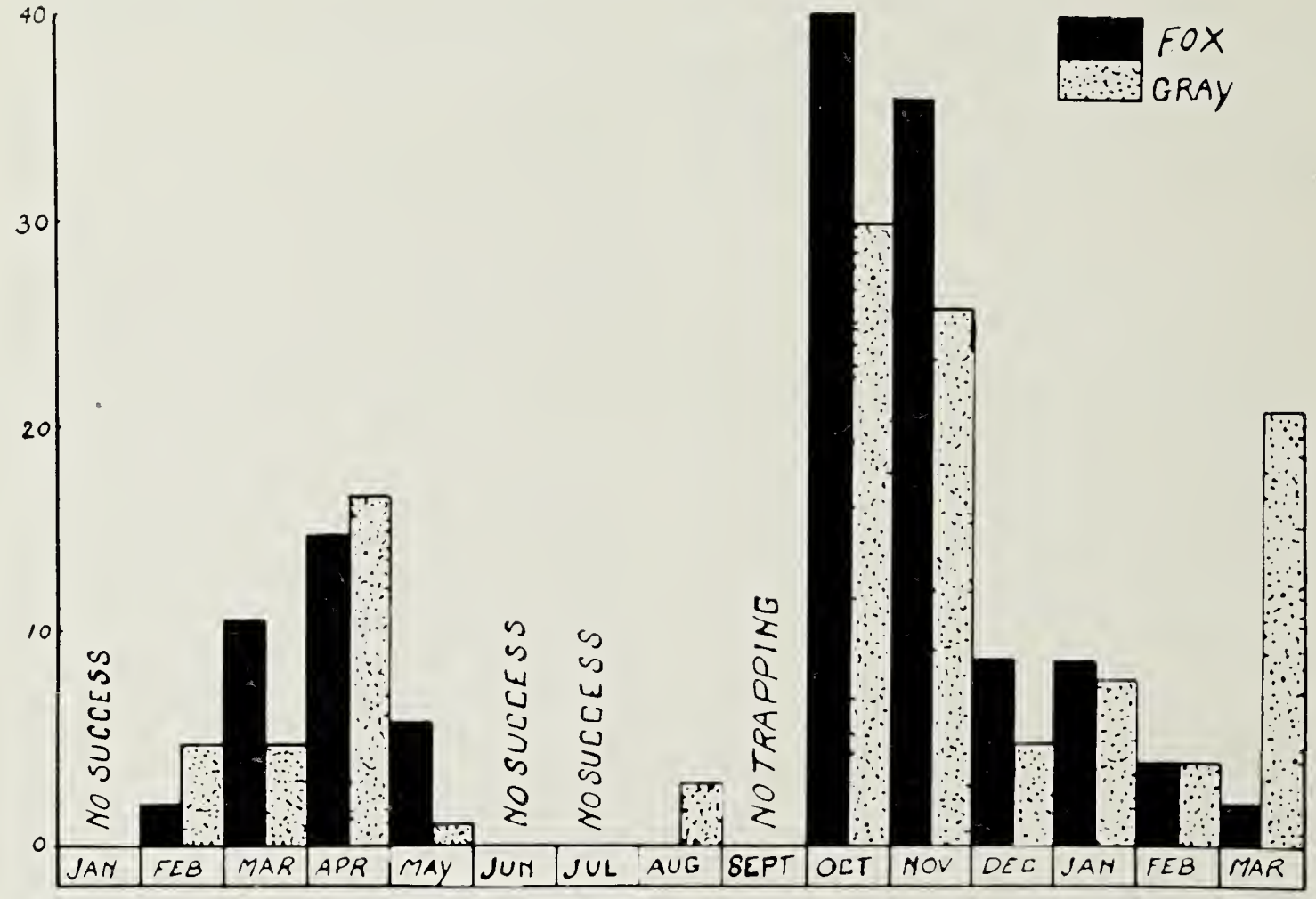


FIG. 1.—Monthly variations in number of fox and gray squirrels caught by live-trapping, Crab Orchard National Wildlife Refuge, January 1952—March 1953.

adult females traveled but 105.1 yards. Average travel range for adult male gray squirrels was 95.1 yards, but only 51.3 yards for the adult females. Baumgartner (1943) reported the travel range of the fox squirrel in Ohio to be 136.7 yards. His studies also indicated that females averaged 24.6 yards less than that of male squirrels. Goodrum (1940) believed the home range of the gray squirrel in Texas to be 200 yards or less.

Only three records of unusually long-range inter-woodlot movements were collected in the present study. All were made by young squirrels. A complete round-trip, with a minimum travel of one-third mile each way, was made by a young gray squirrel. A second young gray squirrel traveled one-quarter mile from the original point of capture in a period of five days. A young fox squirrel showed the longest range—a one-half mile trek from Woodlot F to a small isolated cedar grove.

In addition to these trapping records, five marked squirrels bagged by hunters during controlled hunting in 1952 were killed within the same woodlots where they were last handled. Among these returns were two young gray squirrels which had been toe-clipped in the nest at an age of two and one-half weeks. The ranges of squirrels trapped over a short period of time in any one woodlot were entirely concurrent and gave no indication of territoriality.

## Fall Woodlot Population Levels

Squirrels bagged during controlled hunting in 1952 were carefully examined in order to record

the tag number of all marked individuals and the woodlot where each squirrel was killed. Previous to the September hunt, 58 squirrels (33 gray and 25 fox) had been marked and released over the six study woodlots which totaled 113 acres. The majority of these squirrels were marked between March 1 and June 15. All woodlots were hunted, but marked specimens were returned from only the two larger of the six areas (table 1). The pre-hunting populations were computed for these two woodlots by use of Lincoln index calculations. In Woodlot E, hunters bagged 104 squirrels, but the catch included only four of the 28 animals which had been marked and released there. Applying the index to these figures, the calculated pre-hunting population was determined from the proportion T : 28 :: 104 : 4. The pre-hunting population or T was then 728 squirrels or 4.6 squirrels per acre (table 1). This kill represented 14 percent of the estimated total population. Post-hunting trapping from October 4 to December 10 revealed that eight or one-third of the remaining originally marked squirrels were still in the woodlot. During this period 37 new individuals were marked.

Woodlot F yielded a total kill of 18 squirrels of which only two were marked. Twenty individuals had been marked in this woodlot (table 1). Using these figures in the index, the calculated pre-hunting population was 180 animals or 7.2 squirrels per acre (table 1). The kill constituted 10 percent of the calculated population. This woodlot, though relatively small, had been selected for study because it appeared to be the highest type of range on the area. Post-hunting trapping here indicated that at least four of the 18 marked squirrels in question were still present. Twenty-four new squirrels were handled in the woodlot from October 4 to December 10. This method for estimating fall squirrel populations was employed by Friley (1952) in studying fox squirrels in Michigan. He found a close correlation between yearly calculated populations and corresponding yearly hunter kills.

TABLE 1.—CALCULATED SQUIRREL POPULATIONS OF TWO WOODLOTS AS DETERMINED BY LINCOLN INDEX, CRAB ORCHARD NATIONAL WILDLIFE REFUGE, SEPTEMBER, 1952

| Woodlot | Acres | No. marked Jan.-Aug. | September kill | | Total kill | Calculated population | Calculated population per acre |
|---|---|---|---|---|---|---|---|
| | | | Unmarked | Marked | | | |
| E | 160 | 28 | 100 | 4 | 104 | 728 | 4.6 |
| F | 25 | 20 | 16 | 2 | 18 | 180 | 7.2 |

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# COLLEGIATE

## INHIBITORY EFFECTS OF CERTAIN COMPOUNDS ON MICROSPORON AUDOUINI

NANCY FORSYTH
*Monmouth College, Monmouth*

Tinea capitis, or ringworm of the scalp, is a disease that has been present in our country for many years, although it was not until the last fifteen years that it reached epidemic proportions. Today it has become an increasingly important health problem in the public schools. This paper will deal with one species of ringworm, *Microsporon audouini,* the cause of over 80 percent of the cases among children. Much research has been done in an effort to find a cure for this disease, but, although there are many chemicals which show some promise, there is none which has given the desired result—complete cure in a short period of time. The present research was to test different compounds on the fungus, *in vitro,* to try to find a more promising treatment.

### Past Treatments

Among the compounds tried in the past were podophyllin resin, saturated fatty acids, salicylanilide, iodine, thymol, and asterol dyhydrochloride. These are a few of the more successful, but they, for various reasons, have been discarded. Some took too long to effect a cure and others cured the ringworm but had dangerous after-effects on the patient. Ringworm caused by *Microsporon audouini* seems to clear up when the individual reaches puberty. This was deemed indicative of a connection with the sex hormones, so administration of certain hormones was tried but results were disappointing. This treatment tended to upset the body balance and had little or no effect on the fungus.

There is one treatment which holds promise in curing the most stubborn cases. This is the use of X-ray. It causes spontaneous epiliation of the hair, and is impractical in the majority of cases because the cost is high and there are few technicians who are trained to administer X-rays safely.

### Materials and Methods

A sample of *Microsporon audouini* was obtained from a child whose head showed the fluorescence characteristic of the fungus under a Wood's lamp filter. The sample was placed on a petri dish containing Sabouraud maltose agar. This medium is an excellent substrate for the propagation of molds, especially the parasitic fungi concerned with scalp lesions. The nitrogen-containing Neopeptone and maltose satisfy the nutritional requirements of *Microsporon audouini.* After about a week, growth was noticed. The spores germinated and gave rise to a rather

fine septate mycelium which became distended and developed chlamydospores. Later the mycelium developed pluri-septate spindle spores at their extremities. The colony appeared as a snow-white downy-looking mass. The center of the colony was elevated with radiating furrows extending out from it. As the colonies grew older, they darkened and produced a reddish-brown pigment which diffused into the medium. Under Wood's light the culture fluoresced with bright, clear green dots. From these characteristics, it was determined that the fungus involved was *Microsporon audouini.*

Various methods of inoculating new plates were tried, but the one found most satisfactory was to sterilize an inoculating needle and transfer a bit of the mold with spores to the new dish. Growth is more rapid and there is less chance for contamination if this method is followed.

A .75 cm. hole was cut in the center of each plate to be treated. The compound to be tested was placed in this hole, and the agar was inoculated in six places around the margin of the plate to insure even growth or inhibition of growth. The plates were incubated at room temperature for three to five days. At the end of this time the area of inhibition from the center of the plate was measured and recorded. Each test was run in duplicate.

The compounds chosen for testing purposes were ones which, according to available literature, had not been tried against this species. The first group tested were the antibiotics, chloromycetin, terremycin, and penicillin. The powder form of each of these was dissolved in distilled water to the saturation point. The plates were inoculated and the compounds to be tested placed in the center of each plate. After five days growth, the mold had covered all of the plates, indicating that these antibiotics seemed to have little or no effect on this mold.

The next group of compounds tried included sodium chloride, copper sulfate, sodium carbonate, and ethyl alcohol. The plates were inoculated in a similar fashion. The only compound which showed any inhibitory effect was copper sulfate. The area of no growth measured 4.0 cm. in diameter.

A five percent dilution of phenol was tried on the fungus with fairly favorable results. There was a diameter five centimeters wide of inhibition. Dilutions of four percent, three percent, two percent, one percent, and .5 percent phenol were then tried to determine the effectiveness of smaller dilutions. The results of these smaller dilutions are as follows:

| | |
|---|---|
| 5.—5 cm. | 2.—3.7 cm. |
| 4.—4.7 cm. | 1.—2.1 cm. |
| 3.—4.2 cm. | .5—1.2 cm. |

## Summary

In all, eight different compounds were tested against *Microsporon audouini.* Six of these—chloromycetin, terramycin, penicillin, sodium chloride, sodium bicarbonate, and ethyl alcohol were ineffective against the fungus. Copper sulfate was partially effective. Six dilutions of phenol ranging from 0.5 percent to 5 percent were tried and a definite relationship between strength of solu-

tion and inhibitory efficacy was noted. As dilution was increased effectiveness decreased.

Further research might include trying these chemicals in different bases to increase their effectiveness. Higher percentages of phenol, perhaps up to ten percent could be tried. If a compound is found to be fungicidal it should then be tested on laboratory animals for possible damage of tissues.

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*Illinois Academy of Science Transactions, Vol. 46, 1953*

# REACTION PRODUCTS OF ALDOSES WITH CYSTEINE

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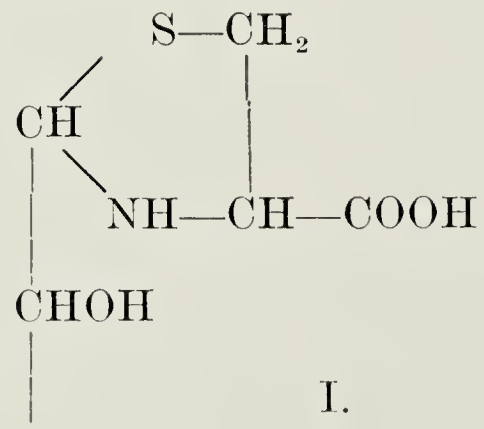
*College of St. Francis and Blockson Chemical Co., Joliet*

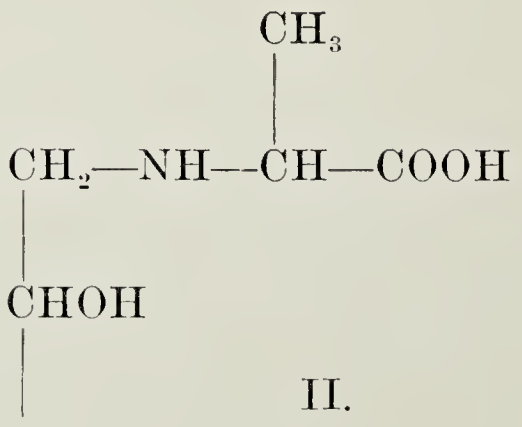
The manner in which carbohydrates are attached to proteins in substances such as the glycoproteins is relatively unknown. In order to shed some light on the subject, various workers have studied the reaction of amino acids with carbohydrates. It was soon found that the most stable amino acid-carbohydrate complexes were formed from cysteine and aldoses. Schubert[1] prepared derivatives of reducing sugars with cysteine and assigned a thiazolidine structure (I) to these substances on the basis of a negative sulfhydryl test with sodium nitroprusside reagent. At the same time, Agren,[2] working in Copenhagen, prepared derivatives of glucose with various amino acids and showed that only the glucose-cysteine reaction went to completion, i.e. the product gave a negative nitroprusside test and in addition gave a negative test for van Slyke (primary amino) nitrogen.



I.

Since the above results indicated the thiazolidine structure (I) for aldose-cysteine derivatives, we prepared these derivatives from D-mannose and D-galactose in order to subject them to reductive desulfurization with Raney nickel. If the substances possess a thiazolidine structure and are stable, then Raney nickel in aqueous alcohol should desulfurize them to the corresponding N-substituted-1-desoxy-1-glykityl derivatives of alanine (II).

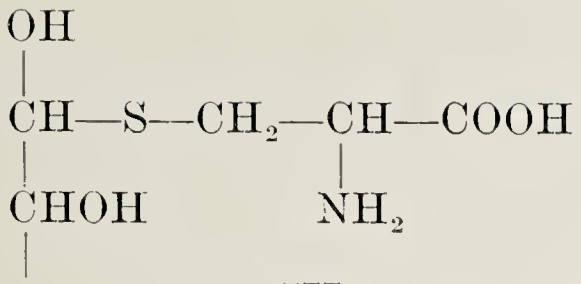
However, reductive desulfurization of the mannose-cysteine derivative actually gave D-mannitol in good yield, and the corresponding galactose derivative gave dulcitol (D-galactitol), i.e. the alcohols corresponding to the original sugars. Assuming the original thiazolidine structure to be correct, these data indicate that under the conditions of reductive desulfurization the aldose-cysteine compounds may be hydrolyzed to their components possibly



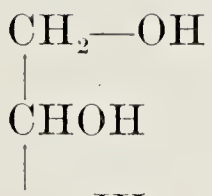
II.

via a monothiohemiacetal of formula (III) which would theoretically yield the alcohols (IV) we obtained from the aldose-cysteine derivatives.

[1] M. P. Schubert, J. Biol. Chem. 130, p. 601, 1939.
[2] G. Agren, Enzymologia, 9, p. 321, 1941.

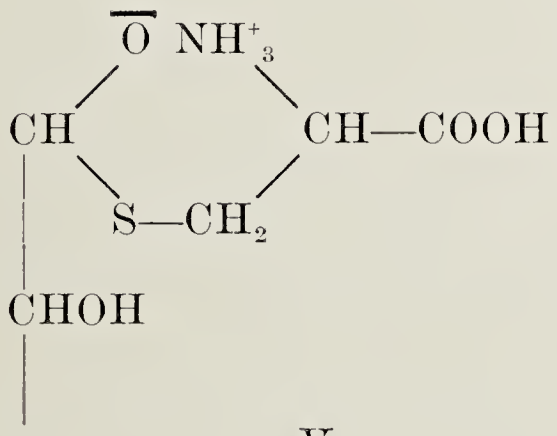


III.

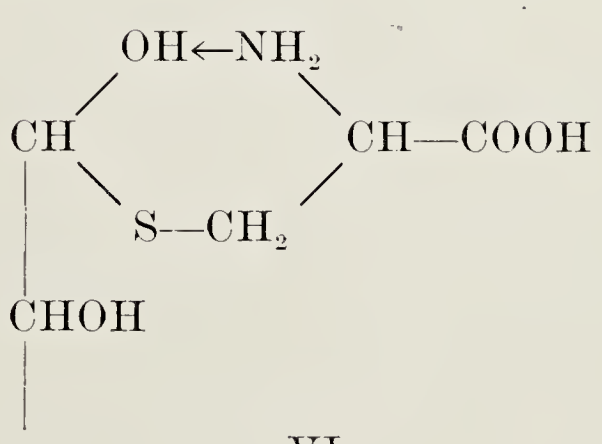


IV.

Monothiohemiacetals have been described previously. Wolfrom, Weisblat and Hanze[3] succeeded in isolating crystalline *aldehydo*-D-galactose ethyl monothiohemiacetal pentaacetate by treatment of the aldehydo sugar with ethyl mercaptan followed by acetylation. It is entirely possible that aldose-cysteine monothiohemiacetal derivatives would owe their stability to the formation of a zwitterion (V) or a chelated structure (VI) which would likewise be desulfurized to the alcohols we obtained.



V.



VI.

Agren actually showed that the crude product of aldoses and cysteine did give positive van-Slyke nitrogen tests but that on purification this amino nitrogen disappeared. We tested our aldose-cysteine products with ninhydrin reagent and obtained a negative test for the amino group but the test became positive after a time indicating slow hydrolysis of the thiazolidine structure. It is questionable whether a structure such as V or VI would give a positive amino nitrogen test immediately.

The question also arose as to whether the aldoses themselves might undergo Raney nickel reduction to the corresponding alcohols. Mannitol was obtained by refluxing mannose with Raney nickel in aqueous alcohol. This reaction is being investigated further as a preparative method for sugar alcohols. In the case of Raney nickel desulfurization of the aldose-cysteine derivatives, the question as to whether the polyhydric alcohols arise from an intermediate monothiohemiacetal derivative or from the aldoses themselves is left unanswered. However, it would be of interest to apply the Raney nickel desulfurization reaction to glycoproteins and attempt to isolate the carbohydrate moiety. Identification of polyhydric alcohol in this experiment would seemingly indicate that the carbohydrate is attached to the glycoprotein through a cysteine linkage.

[3] M. L. Wolfrom, D. I. Weisblat and A. R. Hanze, J. Am. Chem. Soc. 62, p. 3246, 1940.

## Experimental

*Preparation of Mannose and Galactose Derivatives of Cysteine.*—The thiazolidine derivatives of D-mannose and D-galactose were prepared essentially according to the directions of Schubert[1]. The sugar (3.6 g.) and L-cysteine (3.14 g.) were dissolved in 7 ml. of water with shaking. After standing for forty-eight hours, 1.54 ml. of pyridine was added and the mixture was allowed to stand an additional sixty hours at which time 200 ml. of absolute ethanol was added. The crystals which separated on further standing were dissolved in 35 ml. of warm water, filtered, and 150 ml. of absolute ethanol was added to the filtrate. The crystals were collected by filtration and dried. The mannose-cysteine derivative gave a melting point of 170° and the galactose derivative melted at 134°. Schubert[1] reported melting points of 171° and 138° respectively for these substances.

*Reductive Desulfurization of Mannose-Cysteine Complex.*—One gram of mannose-cysteine compound prepared above was dissolved in 50 ml. of 70 percent aqueous ethanol (7 volumes of ethanol—3 volumes of distilled water) and 10 g. of Raney nickel catalyst[4] was added. The mixture was refluxed for five hours and filtered hot. The filtrate was concentrated to dryness in a stream of air and the resultant sirup was taken up in 15 ml. of absolute ethanol. The crystals of D-mannitol which separated weighed 0.45 g. (70 percent), gave a melting point of 163-166° and showed a specific rotation of —0.6° (*C* 1 in water, D line). The recorded physical constants of D-mannitol[5] are m.p. 166° and a specific rotation of —0.21°.

*Anal.* Calcd. for $C_6H_{14}O_6$ : C, 39.56; H, 7.75. Found: C, 39.60; H, 8.00.

*Reductive Desulfurization of Galactose — Cysteine Complex.* — One gram of the galactose-cysteine complex was desulfurized with Raney nickel in the same manner as the mannose derivative. D-Galactitol (dulcitol) (0.4 g., 62 percent) was obtained with a melting point of 185° and the product showed no optical activity. Authentic D-galactitol has a melting point of 188.5° and is optically inactive.[6]

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[4] L. Covert and H. Adkins, J. Am. Chem. Soc., 54, p. 4116, 1932.

[5] W. Pigman and R. Goepp, Jr., Chemistry of the carbohydrates; New York, N. Y., Academic Press, p. 238, 1948.

[6] R. Lohmar and R. M. Goepp, Jr., Advances in Carbohydrate Chem. 4, p. 219, 1949.

# MEMORIALS

## FRANK W. ALDRICH

### 1873-1953

Frank W. Aldrich, aged 79, of Bloomington, Illinois, who died January 25, 1953, at Fort Myers, Florida, was an ardent student of natural history, especially in the fields of botany, archaeology, and ornithology.

He was an active member of the Illinois Academy of Science, Illinois State Archaeological Society, Friends of Our Native Landscape, to mention only a few of the many scientific and business organizations to which he belonged.

Mr. Aldrich was appointed a member of the Illinois State Museum Board of Advisers April 4, 1952, upon retirement of Dr. Fay-Cooper Cole, professor emeritus of anthropology at the University of Chicago.

He was born June 8, 1873, at McLean, Illinois. After graduation from Yale University he joined his father in the banking business in that city. When ready to retire he was reluctant to turn over the goodwill and reputation of the family bank to others, so purchased all the stock and closed the bank's doors.

His vacations from business were devoted to travel and to observations in the fields of his natural history interests. One summer he spent as a member of an archaeological field party led by Professor George Grant MacCurdy of Yale University in investigating paleolithic caves in western Europe. In retirement he spent his time in further study and development of his knowledge in the fields of science. The Bloomington Pantagraph in a recent editorial called him "Nature's Interpreter."

Hazel Funk Holmes, a friend of Mr. Aldrich since her childhood, in a Memoriam written for *Friends of Our Native Landscape,* says:

"Although not a professional, he was a real naturalist. He was also a real archaeologist and an authority on birds, trees and wild flowers. He knew a lot about animals and insects, sea-shells, weather, and many other related interests. . . .

"Frank's vocation was banking. Had he ever written 'The annals of a country banker' (as I often begged him to) it would have been a best seller. He used to regale us with human interest stories about his depositors. That he was an able banker is evidenced by the fact that his bank was one of three in McLean county that remained solvent after the bank holiday of 1932.

"His avocations were so many that he could practice one or more in every season. Birds and wild flowers in Spring; hunting arrowheads and other artifacts along the Mackinaw, or collecting fossils from the Mazon in Autumn."

Mr. Aldrich was anxious that all persons share in his love for nature, and last spring he inserted an ad-

vertisement in the Bloomington Pantagraph offering wild flower roots to anyone interested in starting a garden of their own. More than 150 persons took advantage of the offer.

One of Mr. Aldrich's many contributions to archaeology was the collection of most beautifully chipped flint blades. The blades were found in a gravel pit near Mackinaw, Illinois, and had been scattered by gift and sale by the original finders. Mr. Aldrich, over a period of years, gathered thirty-one of the blades, which Professor Holmes said are "the most skilled work in stone flaking in this country." This collection he gave to the Illinois State Museum and it may be seen in a special case in the west art gallery.

For the last year he was helping prepare a checklist of Illinois birds to be published by the Museum.

—Thorne Deuel.

## JOHN RICE BALL

### 1881-1953

John Rice Ball, professor emeritus of geology at Northwestern University, died March 1, 1953, in Seattle, Washington. Born in Fremont, Ohio, June 26, 1881, he spent the major part of his boyhood years in North Dakota, but completed his secondary education in the preparatory school of the College of Puget Sound in Tacoma, Washington. In the years following between 1900 and 1914, he served as a minister of the Methodist Episcopal Church, holding pastorates in Washington, Montana, and Illinois. In 1905 he was married to Cora Goodman.

Eager to continue his education, he found that opportunity when in Illinois and enrolled in Garrett Biblical Institute in Evanston, and at the same time completed a program at Northwestern University, receiving both a Bachelor of Arts degree from Northwestern and a degree of Bachelor of Divinity from Garrett in 1913.

While studying at Northwestern, his interest in geology was stimulated by Dr. U. S. Grant, then head of the Geology Department, and he determined to make his career in that field. He took his master's degree in geology at Northwestern in 1917 and his doctorate at the University of Chicago in 1927. While a graduate student at Northwestern, he had been a graduate assistant, and in 1918 he was appointed as instructor. From then until his retirement in 1946, he was a member of the faculty of Northwestern University, serving as chairman of the Geology Department from 1943 to 1945.

Paleontology and stratigraphy, with particular attention to the Silurian rocks of the central part of the United States, formed his special field of interest, but his scientific contributions also included physiographic and glacial studies in the Midwest. In pursuance of these interests he served as geologist with both the Illinois and North Dakota Geological Surveys during various summers, and in 1931-32, while on sabbatical leave, he visited many famous Silurian localities and museum collections around the world.

Teaching, however, was his greatest interest and from it he drew his

greatest satisfaction and rewards. Students and colleagues alike remember him with affection and count their association with him as a privilege. His teaching activities extended beyond the university classrooms, and he was generous in contributing his time and experience for the benefit of professional and amateur groups. His publications include a number of papers and pamphlets prepared for non-professional readers.

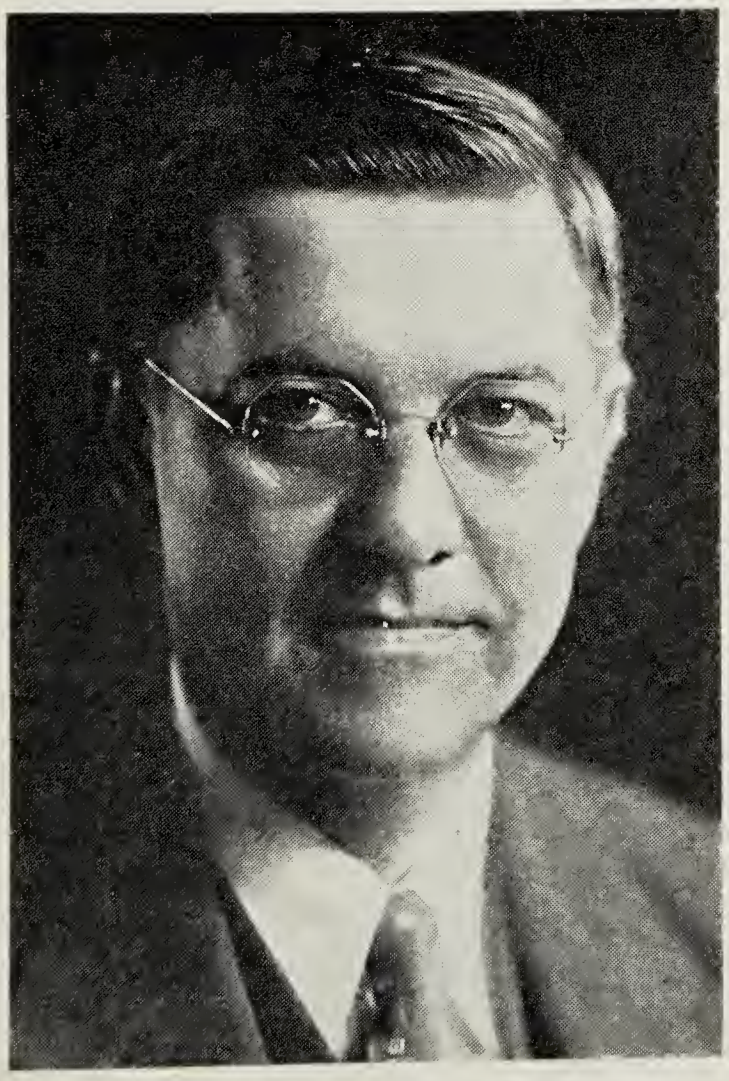
After his retirement from Northwestern, he was professor of geology at the University of Kansas City for four years, and he taught at the University of North Carolina in 1950-51. The following year he returned to his old home in the Pacific Northwest and taught at the College of Puget Sound in Tacoma, rounding out a full half century since his graduation from the preparatory school of the same institution.

He is survived by two children, Clayton G. Ball, of Wilmette, Illinois, and Mrs. Nathan Wilkinson of Seattle, Washington.

—Arthur L. Howland.

## JOHN THEODORE BUCHHOLZ

1888-1951



John T. Buchholz was born in Nebraska, studied at Iowa Wesleyan College and the University of Iowa, and carried on his graduate work at the University of Chicago (Ph.D. 1917). He taught in Arkansas and Texas, and became professor of botany at the University of Illinois in 1929. His association with the Academy was close: its *Transactions* include some of his papers (in Volumes 23, 24, 25, 33, 34, and 38).

His work covered many fields: morphology and embryology (especially of gymnosperms), taxonomy (Arkansas flora, Ozark white cedar, the giant tree Sequoiadendron, Podocarpus, Araucaria and other conifers of New Caledonia), and genetics (especially of Datura). He developed and described various techniques, including preparation of plant materials for study; herbarium practice, especially photography of specimens; use of electron microscope in botanical study.

He was married in 1912 to Olive Peterson, who had also studied botany at the University of Chicago. Their three daughters are Miriam, Christine, and Ruth. Mrs. Buchholz's

death came less than three months before his own, on July 1, 1951.

He received many honors, having been president of the Botanical Society of America; vice-president of the botany section, American Association for the Advancement of Science; vice-president of a section at the International Botanical Congress (Stockholm, 1950), and Correspondent of the Museum of Natural History of Paris. The last was in recognition of his outstanding studies, in the field and elsewhere, of the botany of New Caledonia.

A fairly detailed recounting of his history and activities, with a bibliography of over eighty of his publications, by G. Neville Jones and Oswald Tippō, appeared in *Phytomorphology,* vol. 2, pp. 181-185, 1952.

Dr. Buchholz's many students and friends, and his scientist associates in this and other countries were saddened at the premature termination of a most productive life. The University, the Academy, and the botanists of the country have lost a valued friend.

—A. G. Vestal.

## B. SMITH HOPKINS

### 1873-1952

B. Smith Hopkins was born in Owosso, Michigan, September 1, 1873, and died at Urbana, Illinois, August 27, 1952, a few hours after returning from his summer home in Michigan and a few days before his 79th birthday. Dr. Hopkins did his undergraduate work at Albion College, Michigan, and graduate work in chemistry for the Ph.D. degree at Johns Hopkins University. After teaching high school at Menominee, Michigan, and college chemistry at Nebraska Wesleyan University and Carroll College, he joined the staff of the University of Illinois in 1915, serving as a member of the Chemistry Department until his retirement in 1944. His field of specialization was the chemistry of the rare earth elements, and he achieved international renown for his researches. The high point of his career was probably his discovery of the first new chemical element to be isolated in America. He named this element after his state and University, illinium. Dr. Hopkins was a beloved teacher who made his field of inorganic chemistry live for many generations of students ranging from freshmen to doctoral candidates. He stressed the applications of chemistry in all branches of industry and in every day living. He was the author of several widely used textbooks and many research articles. He was a founder and chairman of the division of chemical education of the American Chemical Society.

Dr. Hopkins was a public spirited member of his community and for several years served as head of the Urbana School Board. He was for many years a member of the Illinois State Academy of Science and served as its president in 1931-32. He was interested in the development of the Junior Academy and some years later in the establishment of a collegiate section. In an introductory talk to the first meeting

of collegiate science students at Urbana in 1942 he spoke enthusiastically about the manifold opportunities for research by undergraduate students in the field of chemistry. Late in his career he directed the setting up by the University of Illinois of an interdepartmental course in physical science taught by representatives of the astronomy, chemistry, geology, and physics departments. Here he set himself to the task of teaching elementary students three new fields of science with the same enthusiasm he had displayed in his many other activities.

Dr. Hopkins was an able scientist, an interested and enthusiastic student of such diverse topics as atomic structure, calendar reform, and intercollegiate athletics, a public spirited citizen, and a sincere friend to his students and his associates in many fields of endeavor. He is survived by Mrs. B. S. Hopkins, two sons and five grandsons.

—Harold R. Wanless.

## JUSTUS STEVENS TEMPLETON, JR.

### 1914-1953

The death of Justus Stevens Templeton, Jr., Geologist, Illinois State Geological Survey, on April 21, 1953, was a tragic loss to his Survey colleagues, to his many friends in the Illinois Academy of Science, and to geologists throughout the country. Dr. Templeton was fatally injured when struck by a falling boulder while he was studying a rock exposure along the Mississippi River in St. Paul, Minnesota.

Dr. Templeton was born at Princeton, Illinois, on July 11, 1914, the son of Mrs. Templeton and the late J. S. Templeton, Sr. His childhood was spent on the family farm, in Bureau County, which his great-grandfather, Justus Stevens, had purchased from the government in 1849. He grew up with a love for the Fox River country of northern Illinois that culminated in his becoming an authority on the geology of that region.

Dr. Templeton attended the Harris School in Chicago but returned to the Fox River country to graduate from the Dixon High School. He followed his father's footsteps to Princeton University and received his A.B. degree in geology in 1936. He took graduate studies at the University of Wisconsin from 1936 to 1938 and then transferred to the University of Illinois where he took his Doctor of Philosophy degree in 1940. For his doctorate thesis he made a detailed study, under the auspices of the State Geological Survey, of the Woosung, Illinois, quadrangle, the name then applied to the topographically mapped part of the Sterling quadrangle.

After receiving his Ph.D. degree, Dr. Templeton worked for the Carter Oil Company in South Dakota in 1941. He was Assistant State Geologist of North Dakota and Assistant Professor at the University of North Dakota in 1942. He was an instructor at the University of Illinois, 1942-1943. In 1943 he joined the U. S. Navy and had the rank of Lieutenant (j.g.) in the Naval Intelligence Division from 1943 to

1945. He was geologist for the Naval Petroleum Reserve in northern Alaska in 1946. Following naval service he joined the staff of the State Geological Survey in 1946, rising from Assistant Geologist, through Associate Geologist, to Geologist in 1948.

Dr. Templeton was a specialist in Cambrian and Ordovician stratigraphy. He was an outstanding student of the Middle Ordovician strata of the Mississippi Valley, and he had a wide acquaintance with these rocks throughout the United States and Canada. In areal geology studies in the Sterling and Oregon quadrangles he found an ideal outlet for his great energy and for his interest in precise mapping and detailed study. Every ravine held a challenge for him. His field notes and graphic sections are a model of detail, accuracy, and neatness.

Dr. Templeton was congenial, cooperative, and gentlemanly. His friendliness and boundless enthusiasm won him many friends. All knew him as "Steve."

He is survived by his wife, the former Dorothy Damon, his daughter, Ellen, aged 10, and his son, Justus Stevens III, aged 7, who reside in Champaign, his mother, Mrs. J. S. Templeton, Sr., of Princeton, and a sister, Mrs. Anne McKim, who lives in Fort Worth, Texas.

Dr. M. M. Leighton, Chief of the Survey, expressed the feelings of his colleagues when he said: "The staff of the State Geological Survey suffers a great personal and professional loss in the tragic death of Dr. Templeton. He gave untiring energy to his research, pursued his studies in a devoted scientific spirit, and won the admiration of his colleagues in stratigraphic geology throughout the country. Personally, he gave himself constructively to the *esprit de corps* of the staff. Dr. Templeton will be sorely missed."

—H. B. Willman.

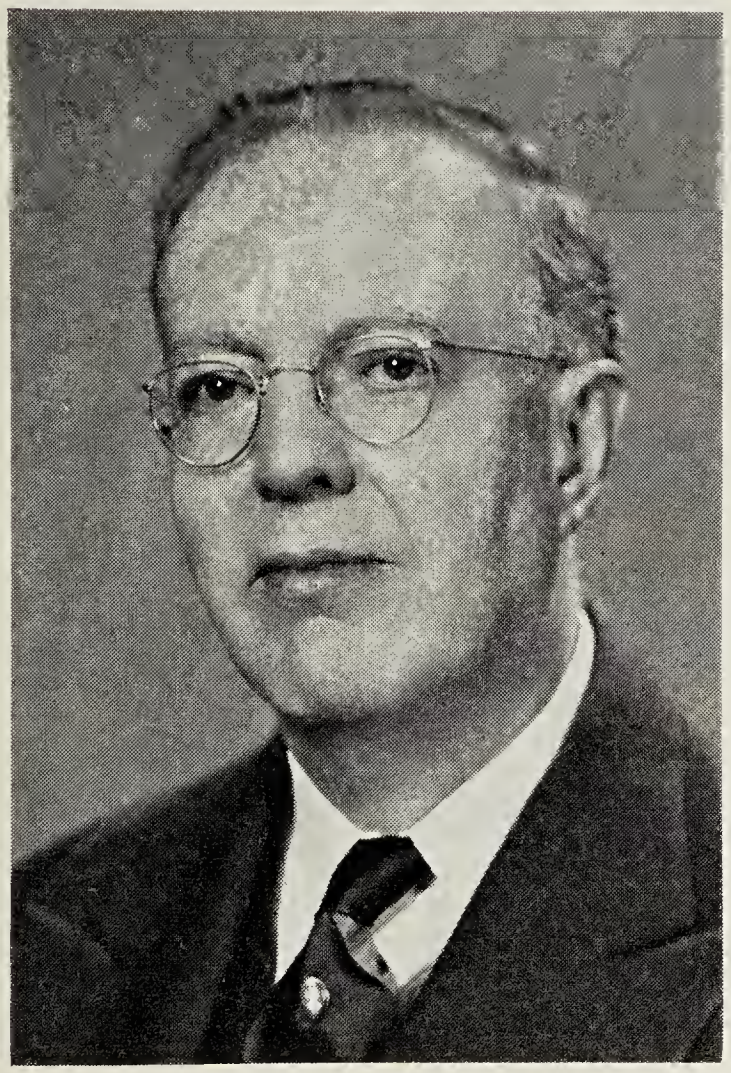
## HARLEY JONES VAN CLEAVE

### 1886-1953

Harley Jones VanCleave was born October 5, 1886, at Knoxville, Illinois. He attended Knox College, receiving the B.S. degree in 1909, then went to the University of Illinois, studying under H. B. Ward and receiving the M.S. degree in 1910, and the Ph.D. degree in 1913. He was appointed an instructor in the Department of Zoology at the University of Illinois in the same year and served the University faithfully until his death on January 2, 1953. In 1929 he reached the rank of professor, and was first chairman, then acting head, of the Department of Zoology from 1936 to 1939. In 1948 he was appointed research professor. During various summers he was on the staff of the Puget Sound Marine Station, the Roosevelt Wild Life Forest Experiment Station, and other similar institutions.

In 1914 Dr. VanCleave married Bernice Ford. He is survived by Mrs. VanCleave and one of their two children, Philip. Their daughter Dorothy died only a few months before her father.

Dr. VanCleave was a man of many



facets, but foremost in his thinking at all times was the good of the University, the furtherance of science, and the success of his students. His systematic work was chiefly on the parasitic worms belonging to the Acanthocephala, and his published works are lasting contributions to the literature of this group. He wrote numerous papers on other groups of invertebrates, many in order to clarify the systematics of the local fauna around which he built his famous courses in Faunistic Zoology.

This gives a direct clue to Dr. VanCleave's greatest joy—teaching. Into his courses he interwove material on the philosophy of science and the challenge of investigation, ever alert to encourage the zest for research in his students. He had a warm personality and was always ready and willing to talk over problems with students, to help them to obtain material, and to make constructive suggestions concerning their research difficulties.

Dr. VanCleave realized more than most the critical need of scientists for well-functioning scientific organizations. His own efforts in this field were far greater than many realized. For nine years he served the American Microscopical Society, first as treasurer, then as secretary and editor for their *Transactions*. He served on editorial boards for Biological Abstracts, the Illinois Biological Monographs, and the American Midland Naturalist. He was active in many other learned societies, serving as contributor of papers or organizer of meetings. In these and in the University he took an active part on many committees, dispatching his duties meticulously and with a deep sense of responsibility to thus serve the whole. In recognition of this service he was elected President of the American Microscopical Society in 1931, President of the American Society of Parasitologists in 1947, and Chairman of Section F and Vice-president of the AAAS in 1949. Of our Illinois Academy of Science he was Vice-president in 1924 and President in 1928.

His students and his host of other friends will long remember "Doctor Van," as a diligent and productive scientist, an inspiring teacher, beloved friend and able counselor, and as a man of high resolve who gave unstintingly of his time in the service of science.

—Herbert H. Ross.

# WARREN GOOKIN WATERMAN

## 1872-1952

Warren Gookin Waterman was born to Edwin Southworth and Martica Gookin Waterman in Southport, Conn., in 1872. He married Anna Mueller, daughter of Martin and Anna Maria Febles Mueller, in 1898. Mrs. Waterman died in 1944. They had three children, Warren G., Alice Southworth, and John French.

Warren Waterman spent his boyhood on the estate of his grandparents, where he wandered in the woods and along a brook, developing the love of nature which persisted throughout his life. He attended Southport Dames School, directed by Miss Smith, who encouraged him to read extensively, particularly in the field of natural science. He did not attend high school, but received a diploma from Bridgeport High School by examination.

He received his B.A. in 1892 and his M.A. in 1907 from Yale University, and his Ph.D. in botany from the University of Chicago, in 1917. He taught at Fisk University, Nashville, Tennessee, from 1896 to 1911; at Knox College, Galesburg, Illinois, from 1912 to 1915; and at Northwestern University, Evanston, Illinois, from 1917 until his retirement in 1937. He was made Professor and Chairman of the Botany Department in 1928.

He was a fellow of the American Association for the Advancement of Science; former president of the Illinois Academy of Science; member of the Board of Advisors, Illinois State Museum, and of the Conservation Council of Chicago, the Michigan Academy of Sciences, and the Botanical Society of America. He held memberships in the Congregational Church and the University Clubs of Evanston and Chicago. He was an honorary member of the Evanston Garden Club.

During his years at Northwestern University, he taught courses in ecology and landscape gardening. He was an advocate of natural, rather than formal, garden planting. He often took groups of students to the Frankfort area of Michigan and to the Rocky Mountains for summer field courses in ecology. His principal research interest was the ecology of dunes areas. He studied the region around Sleeping Bear Dune on Point Betsie, in Benzie and Leelanau counties, and wrote several articles on his work. He also published a book on plant communities. During his chairmanship, the botany department grew in staff and student body.

After his retirement, he moved to his farm, River Bend, near Frankfort. He built a house on a hillside, overlooking the beautiful valley of the Betsie River. In the spring and summer, he tramped over the country, studying the haunts and habits of native orchids, and in the fall, he hunted with his dogs. He probably knew more about wild orchids, especially the showy lady-slippers (*Cypripedium reginae* Walt.), than any other person. He located probably all of the stations where they grow within a radius of 50 miles of his home and visited them at least once a year. He talked to old settlers about the abundance and dis-

tribution of the wild orchids in former years, and crusaded to prevent their extermination by writing articles for newspapers and magazines and by preparing educational exhibits at flower shows. He had accumulated voluminous notes for a monograph on the lady-slipper, and had published two articles in the bulletin of the American Orchid Society.

Photography was one of his hobbies, and he pioneered in Lumier color photography long before the introduction of kodachrome. Coincident with his retirement, he began painting in oils, and his love of plants, of the Michigan dunes, and of his farm is expressed in his paintings.

He passed away on November 15, 1952, and rests in the Benzonia cemetery, in the heart of the country he loved.

—Margery C. Carlson.

# ACADEMY BUSINESS

## SECRETARY'S REPORT OF THE BUSINESS OF THE ILLINOIS STATE ACADEMY OF SCIENCE FOR THE YEAR MAY 4, 1952 TO MAY 9, 1953

Compiled by PAUL R. SHAFFER, *Secretary*

The 46th annual meetings of the Illinois State Academy of Science were held on the campus of Western Illinois State College, Macomb, Illinois, on May 8 and 9, 1953. The section programs included 105 papers, and total attendance at the section meetings was about 400 persons.

The general morning program on Friday, May 8, included the Presidential Address by Dr. Ekblaw, entitled "Twenty-five Years of Engineering Geology in Illinois." Dr. Vernon L. Nickell, State Superintendent of Public Instruction, spoke on "Science in High School Curricula."

The Junior Academy program, under the guidance and direction of Miss Joan Hunter, had wide appeal and was very active. More than 400 exhibits that won first place awards at the district exhibits throughout the state, were shown at Macomb. More than 850 projects were prepared for the district meetings. During the past year, 170 clubs or class groups were affiliated with the Junior Academy, and more than 4500 students participated in the program, from clubs with a very few members to some with a membership of 175 persons. A special time was set aside in the program for the Senior Academy members to visit the Junior Academy exhibits and to discuss them with the exhibitors.

The annual banquet was held Friday evening in Caroline Grote Hall on the campus. The group adjourned to the auditorium of the Main Building for the conclusion of the recessed business meeting where winners in the 12th Annual Science Talent Search were presented with certificates by Dr. F. H. Reed, Chairman of the Science Talent Search Committee. This year 30 high school students from the state received recognition. Two of the winners were awarded a Washington trip and the opportunity to compete for a national award. There were 15 National Honorable Mentions and 13 additional State Honorable Mentions.

The annual public lecture was presented by Dr. William L. Everitt, Dean of the College of Engineering at the University of Illinois. Dean Everitt presented a very interesting and enlightening illustrated lecture entitled "Color Television."

### COUNCIL MEETINGS

The Council held four meetings during the year. The first meeting was held in the U. S. Grant Hotel in Mattoon, Illinois. At this meeting the Council accepted the invitation of Western Illinois State College to meet on its campus for the 46th annual meetings on May 8 and 9, 1953. Dr. H. W. Crall was elected Second Vice-President in charge of local arrangements.

Two new members were appointed to the Publications Committee with terms to expire in 1955. They were Dr. Oswald Tippo and Dr. L. F. Audrieth.

Miss Jane V. Olson was appointed Technical Editor for the year.

The second meeting of the Council was held on November 8, 1953, in room 101 Natural Resources Building in Urbana with Dr. George E. Ekblaw presiding. The reports of the Secretary and Treasurer were made and approved. Dr. Thorne Deuel was chosen as Chairman of the Committee on Conservation of Archaeological and Historical Sites to replace Dr. John B. Ruyle, deceased.

J. S. Ayars was approved as Publicity Advisor to strengthen the public relations and publicity aspects of Academy activities.

The treasurer was instructed to ascertain how much money from life memberships belongs in the Foundation Fund.

A series of reports by Section Chairmen and Standing Committee Chairmen was submitted. Dr. H. F. Thut reported for the Research Grants Committee, Dr. F. H. Reed for Science Talent Search Committee, Dr. C. L. Kanatzar for the Sustaining Membership Committee and

Miss Joan Hunter for the Junior Academy. Dr. Percival Robertson reported on his activities as academy delegate to the AAAS, Dr. H. J. Fuller on the Collegiate Section, and Dr. G. R. Yohe for the Chemistry Section. Mr. Gideon H. Boewe reported that last year 350 new members were added by May 15 and that there were 53 new members obtained between May 15 and November 8, bringing the membership up to about 1200.

The third meeting of the Council was held on February 21, 1953, in room 101 Natural Resources Building, Urbana, with Dr. George E. Ekblaw, presiding. Representatives of the Junior Academy were present and reported on their activities in preparation for the 46th annual meetings and their district meetings. Dr. H. W. Crall submitted an outline of events for the 46th annual meetings for the Senior and Junior Academies.

There were reports from the Section Chairmen and the Chairmen of Standing Committees.

The treasurer reported on his research activities in regard to the establishment of the Permanent Fund of the Academy. His report was followed by three actions of the Council.

1. The sum of $1200 be designated as of this date as the Life Membership Fund portion of the Permanent Fund.
2. That $200 or whatever additional money is needed be added to the money obtained from the sale of the Meyer Leasehold Certificates and a $500 U. S. "K" bond be purchased and added to the Permanent Fund to bring it up to $3000.
3. That the remaining $1800 in the Permanent Fund (after the purchase of the $500 bond above) be designated as of this date as representing additions to the Permanent Fund from accumulations in the Academy Treasury.

The fourth meeting of the Council was held Thursday evening May 7, 1953, at the Lamoine Hotel in Macomb with Dr. George E. Ekblaw presiding. Mr. Lewis Hollmeyer from the office of the State Superintendent of Public Instruction was introduced by the President. Dr. Crall reported that local arrangements for both the Senior and Junior Academies were made. Preliminary reports from the Officers, Committee Chairmen, and Section Chairmen were presented. Final reports were presented to the entire membership at the annual business meeting on Friday, May 8, 1953 and are included on subsequent pages. One significant action not included later concerned the possible publication of abstracts. The Council voted not to publish abstracts.

## ANNUAL BUSINESS MEETING

The annual business meeting of the Illinois State Academy of Science was held May 8, 1953, in the Auditorium of the Administration Building of Western Illinois State College at 5:00 p.m. with President G. E. Ekblaw presiding.

The report of the Secretary, which follows, was accepted.

The minutes of the business meeting of the 45th annual meetings held at Eastern Illinois State College, Charleston, have been published in the *Transactions*. They include deliberations and actions of the Council and the various committees of the Academy, the reports of the Treasurer, the Auditing Committee, the Nominating Committee and the Resolutions Committee.

The major activities of the Council throughout the past year were summarized and mailed to each member along with the Program for the 46th annual meetings in the form of the President's letter.

Mr. President, I move the acceptance of the report of the 45th annual business meeting as printed in the *Transactions* and the summary of this year's activities as included in the President's letter.

Dr. Walter B. Welch gave the Treasurer's report which follows. He moved acceptance of the report subject to confirmation by the Auditing Committee. Dr. Percival Robertson seconded the motion which passed.

## REPORT OF THE AUDITING COMMITTEE

The report of the Auditing Committee was presented by Mr. C. L. Foote. He moved acceptance of the report which follows. H. R. Wanless seconded the motion, which passed.

Your auditing committee has audited the accounts of the Treasurer, Walter B. Welch, for the period of May 1, 1952 through April 30, 1953. We find the following:

| | |
|---|---|
| Balance 5-1-52 | $2,310.45 |
| Receipts | 3,473.44 |
| Total | $5,783.89 |
| Expenditures | 2,835.23 |
| Difference | $2,948.66 |
| Outstanding checks | 169.29 |
| On deposit 4-30-53 | $3,117.95 |

## REPORT OF THE TREASURER

For the Year May 1, 1952 to April 30, 1953

| | | |
|---|---|---|
| Balance on hand April 30, 1952 | | $2,310.45 |
| **Receipts** | | |
| Dues: | | |
| Annual Regular | $2,350.30 | |
| Annual Sustaining | 470.00 | |
| Life | 100.00 | |
| Interest on United States Saving Bonds | 56.90 | |
| Sales of Transactions | 10.00 | |
| Sales of Reprints | 79.24 | |
| Registration Fees—Eastern Illinois State College | 126.50 | |
| Sale of three shares of the Meyer Block Leasehold | 280.50 | |
| | | 3,473.44 |
| Total Receipts | | $5,783.89 |
| **Expenditures** | | |
| Council Expenses | 73.41 | |
| Treasurer's Office Expenses | 207.31 | |
| Secretary's Office Expenses | 574.63 | |
| Editor's Office Expenses | 13.19 | |
| Membership Chairman's Expenses | 28.88 | |
| Section Chairmen's Expenses | 51.80 | |
| Science Talent Search Winners | 234.00 | |
| Dues to other Organizations | 8.00 | |
| Junior Academy Expenses | 640.36 | |
| United States Savings Bonds | 1,000.00 | |
| Refunds on Overcharges | 3.00 | |
| Bank Charges | .65 | |
| Total Expenditures | 2,835.23 | |
| Outstanding Checks | 169.29 | |
| Checks that cleared Carbondale National Bank as of April 30, 1953 | | 2,665.94 |
| Balance in Carbondale National Bank | | $3,117.95 |

### Statement of Resources, April 30, 1953

| | |
|---|---|
| Balance in the Carbondale National Bank | $3,117.95 |
| United States Savings Bonds | 3,000.00 |
| Total Resources | $6,117.95 |
| Permanent Fund established by the Council February 20, 1953 | $3,000.00 |

(Signed) WALTER B. WELCH, *Treasurer*

RESOURCES 4-30-53

| | |
|---|---|
| United States Bonds | $3,000.00 |
| Balance in Carbondale National Bank | 3,117.95 |
| Total | $6,117.95 |

($169.29 of this total of $6,117.95 are committed for the payment of the outstanding checks.)

The auditing committee also made a sampling test of the paid membership in the Academy and obtained a perfect result on the samples taken.

(Signed) K. VAN LENTE, *Chairman*
C. L. FOOTE,
S. E. HARRIS.

The following letter was received by Dr. Kenneth Van Lente:

This is to certify that the account of the Illinois State Academy of Science with us showed a balance of $3,117.95 at the close of business on April 30, 1953.

Very truly yours,
(Signed) JOHN T. MARS,
*Vice-President*,
Carbondale National Bank.

TO WHOM IT MAY CONCERN

This will certify that on May 4, 1953 I saw taken from and replaced in a safety deposit box at the Carbondale National Bank, Carbondale, Ill. the following United States Government Bonds issued in the name of the Illinois State Academy of Science:

| | |
|---|---|
| 2 K bonds at $500.00 each | $1,000.00 |
| 20 G bonds at $100.00 each | $2,000.00 |
| Total | $3,000.00 |

(Signed) K. VAN LENTE.

The Nominating Committee consisted of H. R. Wanless, chairman, H. J. Eigenbrodt, F. M. Fryxell, and H. F. Thut. Dr. Wanless presented a slate of officers for 1953-54 and a roster of committee chairmen and committee personnel. This list will be published in the program for the 47th annual meeting and later in the *Transactions*. Dr. Wanless moved acceptance of the report subject to nominations from the floor. W. M. Merrill seconded the motion. There were no nominations from the floor and the motion carried.

Dr. H. B. Willman reported for the membership committee and stated that active membership in the Academy was now over 1100 members. Dr. H. R. Wanless moved that the Academy express its appreciation for the splendid work done by the membership committee. Dr. W. M. Merrill seconded the motion which carried.

Dr. H. J. Fuller reported for the Committee on Teacher Training. The report consisted of two parts which follow. Dr. Fuller moved acceptance of the first part of the report, W. W. Wantland seconded the motion which carried. Dr. Fuller, after including some changes suggested from the membership, moved acceptance of the second part of the report. The motion carried.

The Illinois State Academy of Science recommends to the State Superintendent of Public Instruction and to the State Examining Board of Illinois the study and consideration of the following for inclusion in the next State Accrediting Bulletin:

I. That, in order to improve the science training of secondary school teachers of science, the following minimal academic requirements for the training of such teachers be made a part of teacher-certification requirements in Illinois:

1. For the preparation of teachers of biology: 24 semester hours of college work in biological sciences, distributed thus: 12 hours in botany (including bacteriology) and 12 hours in zoology (including one course in human physiology).

2. For the preparation of teachers of physical science: 24 semester hours of college work distributed thus: 10 hours of chemistry, 10 hours of physics, and 4 hours of geology and/or astronomy or meteorology.

3. For the preparation of teachers of general science: 36 semester hours of college work distributed thus: 18 hours in biological sciences and 18 hours in physical sciences (physics, chemistry, geology, astronomy, meteorology).

The Illinois State Academy of Science further recommends the study and consideration of the following for inclusion in the State Accrediting Bulletin by 1960:

II. That the following minimal academic requirements for the training of such teachers be made a part of teacher-certification requirements in Illinois by 1960:

1. For the preparation of teachers of biology, 32 semester hours of college work, distributed thus: 16 hours of botany (including bacteriology) and 16 hours of zoology (including human physiology).

2. For the preparation of teachers of physical science, 32 semester hours of college work, distributed thus: 12 hours of chemistry, 12 hours of physics, and 8 hours of geology and astronomy or meteorology.

3. For the preparation of teachers of general science: 48 semester hours of college work, distributed thus: 24 hours in biological sciences and 24 hours in physical sciences.

*Committee on teacher-training of the Illinois State Academy of Science:*

H. J. Fuller, *Chairman*
A. Frances Johnson,
F. M. Fryxell,
J. W. Neckers,
E. L. Stover.

The business meeting recessed at 5:45 p.m. for the annual banquet in Caroline Grote Hall.

Following the banquet the business meeting was resumed at 7:30 p.m.

Dr. C. L. Kanatzar reported an increase in the number and the total contribution of sustaining members for the past year.

Dr. H. R. Wanless moved that persons who had applied for membership during the past year and who had met the qualifications for membership be elected to membership. Dr. H. F. Thut seconded the motion which carried.

The Conservation Committee submitted a Resolution which had been tabled from the business meeting of last year for the purpose of further information and study. Percival Robertson moved its adoption. Dr. J. M. Spaeth seconded and the motion carried. The Resolution follows:

CONSERVATION

*Whereas*: the Illinois Academy of Science feels the need for a concise and well-worded statement of policy for the treatment of the nation's natural resources, and

*Whereas*: such a statement is to be found in the statement of Policy For Renewable Natural Resources, prepared by the Natural Resources Council of America, therefore

*Be it resolved*, that the Illinois State Academy of Science at its annual meeting held in Macomb, Illinois, May 8, 1953, endorses the statement of policy prepared by the Natural Resources Council, and further

*Be it resolved*, that a copy of this action be sent to the proper officials of said Council.

Dr. G. W. Thiessen extended an invitation to the Academy to hold its 47th annual meetings at Monmouth College, Monmouth, Illinois. W. B. Welch moved acceptance of the invitation, G. R. Yohe seconded the motion, and the invitation was accepted.

Dr. C. W. Hudelson of Illinois State Normal invited the Academy to Normal for 1957.

Dr. H. F. Thut reported that the Research Grants Committee had requests for grants which amounted to more than $1500. The committee awarded 4 grants which totalled $310 as shown below. Dr. F. H. Reed moved approval of the grants, R. A. Evers seconded, the motion carried.

The Research Grants Committee makes the following grants:

1. To TROY C. DORRIS of Homer, Illinois, and of Quincy College, $100 for a study of the seasonal variations in the bottom fauna of the streams around western Illinois and the relation of bottom organisms to the food habits of fishes.

2. To DOROTHEA FRANZEN of Illinois Wesleyan University, $100 for a study of the holotypes, cotypes, and paratypes of gastropod molluscs of Illinois and for the collection of fixatives, stains, slides and other materials in the study of these molluscs.

3. To SISTER M. JOAN, Department of Chemistry, College of St. Francis, Joliet, $10 for chemicals necessary for the study of detergents.

4. To W. M. GERSBACHER, Department of Zoology, Southern Illinois University, $100 for the purchase of materials and equipment for the study of the ecology of streams of southern Illinois.

(Signed) H. F. Thut, *Chairman*

Dr. F. H. Reed presented the 30 Illinois winners in the Westinghouse 12th Annual Science Talent Search. Twenty-seven of the thirty were present and given certificates from the Academy for this outstanding achievement.

The Resolutions Committee which consisted of H. B. Mills, H. E. Phipps, W. W. Wantland and A. G. Tillman submitted 10 resolutions to the Academy. Dr. A. G. Tillman presented the report in the absence of Dr. H. B. Mills. The following eight resolutions were adopted by the Academy.

CONDOLENCES

The attention of the Academy has been called to the recent passing of Mary

Bruner Tehon, wife of past President Leo R. Tehon.

It is requested that the Secretary be instructed to extend to Dr. Tehon the condolences of the Academy in his hour of bereavement.

## SECRETARY

In recognition of his faithful services as Secretary, the Academy expresses its sincere appreciation to Paul R. Shaffer.

## IN MEMORIAM

The attention of the Academy is regretfully turned to the following list of members who have passed away since the last Annual Meeting:

| | |
|---|---|
| F. W. Aldrich | H. O. Lathrop |
| J. R. Ball | J. B. Rolle |
| J. W. Barwell | Marguerite Simmons |
| J. T. Buchholz | C. P. Stroud |
| H. W. Cromwell | J. S. Templeton |
| D. W. Deal | H. J. VanCleave |
| E. H. Ehrman | H. D. Waggoner |
| R. C. Friesner | C. J. Weinman |
| B. Smith Hopkins | W. G. Waterman |

## AMERICAN ASSOCIATION FOR ADVANCEMENT OF SCIENCE

*Be it resolved*:

The Illinois State Academy of Science subscribes to the basic principle that close cooperation between scientists and scientific societies is highly beneficial to our country and to mankind.

The Illinois Academy at this time expresses its sincere appreciation for the help derived from the close cooperation of the American Association for the Advancement of Science with the Academy, and for many services rendered, especially in recent years. On its part the Academy wishes to cooperate in all appropriate ways with the American Association. It expresses its conviction that this sort of cooperation will expand into even greater mutual helpfulness for all concerned, and increasing benefit to the nation.

## GEOLOGICAL FIELD TRIPS

*Whereas*: for many years the State Geological Survey of Illinois has sponsored Earth History Field Conferences for science teachers and for other interested persons, in several different sections of this state, and

*Whereas*: the burden for organizing and for conducting these trips was carried by Dr. M. M. Leighton, Dr. George E. Ekblaw, Mr. Don Carroll, and Dr. Gilbert O. Raasch, along with other members of the Geological Survey, and

*Whereas:* the science teachers of Illinois and others who accompanied them on these trips wish to express their sincere thanks to the members of the State Geological Survey,

*Be it resolved*, that the Secretary be directed to send a copy of this resolution to the former and the present members of the State Geological Survey mentioned above.

## APPRECIATION TO THE HOSTS

*Whereas*: the excellent arrangements and provisions for this 46th annual meeting of the Illinois State Academy of Science by its host, the Western Illinois State College, have contributed greatly to the success of this meeting, and

*Whereas*: Mr. Dale Kinley, Manager of the Macomb Chamber of Commerce, furnished both space and office help for securing the accommodations for the Senior and for the Junior Academy members, and

*Whereas*: Mr. R. E. Stuart supplied the room for the Registration Center for the Junior Academy of Science,

*Whereas*: Sigma Zeta Society of Western Illinois State College has devoted many hours to planning arrangements for members of the Senior and Junior Academies

*Be it resolved*, that this Academy express its heartfelt thanks to Dr. W. H. Crall, Second Vice-President, who was in charge of the local planning, to Mr. D. Kinley, to Mr. R. E. Stuart and to all other persons who served in any capacity in caring for the interests and the activities of the Academy members during this meeting, and that the Secretary send a copy of this resolution to the people and organizations named above.

(Signed) Harlow B. Mills, *Chairman*
Harris E. Phipps,
Wayne W. Wantland,
Arthur G. Tillman.

## FREEDOM OF SCIENTIFIC INQUIRY

*Whereas*: as scientists, we are opposed to Communism and all other forms of totalitarian philosophies that tend to restrict free inquiry,

*Whereas*: as scientists who are also citizens of the United States, we recognize the threat of Communism to our constitutional form of government and we regret that some scientists—though the number is small—have through

their betrayal of trust sought to jeopardize our national security,

*Whereas*: also, as scientists and as citizens of the United States, we favor legislation that, within the framework of our Constitution and our traditional American ideals of justice, will preserve our cherished right of free inquiry, unhampered by fear and unrestricted by political considerations,

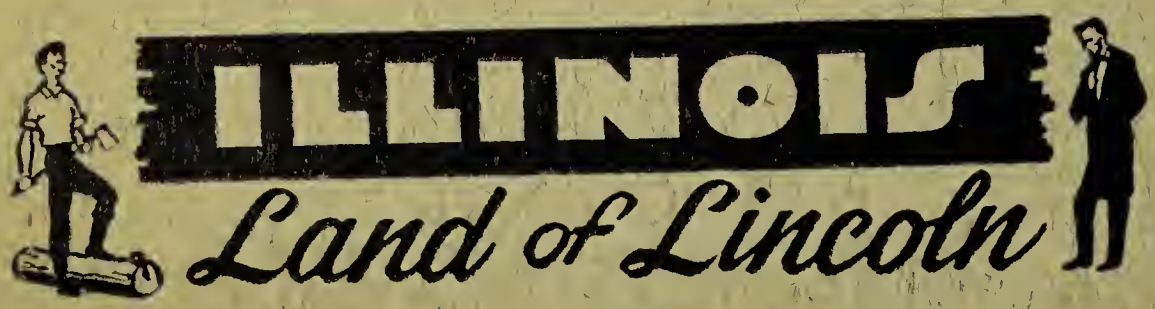
*Be it resolved*, that the Illinois State Academy of Science oppose any legislation that in the name of freedom restricts freedom; that in the name of security, jeopardizes security; that to overcome one totalitarianism, imposes another.

While we find much to commend in the expressed purpose of certain so-called antisubversive legislation, we oppose any legislative action that restricts the dissemination of scientific information and freedom of scientific inquiry.

## TEACHING CERTIFICATES

*Whereas*: it is reported that bills are being prepared by the Office of the State Superintendent of Public Instruction, which if passed, would permit the issuance of temporary teaching certificates to people with as little as one year of college training, therefore

*Be it resolved*, that the Illinois State Academy of Science go on record as opposing these bills since it appears that such legislation would be detrimental over the years to the best interests of improving instruction in the public schools and BE IT FURTHER RESOLVED that the Secretary be directed to send a copy of this resolution to the proper committee of the Legislature.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